A Comparative Analysis of the Financial Strength of Major Ports on the East Coast of India

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DECLARATION

I, GAVIT AARKIT KALURAM, bearing Register Number: 2303305017, student of MBA International Transportation and Logistics Management, at School of Maritime Management, Indian Maritime University, Chennai Campus, hereby declare that the project report titled

"A Comparative Analysis of the Financial Strength of Major Ports on the East Coast of India" is my original work. This report is being submitted in partial fulfilment of the requirement for the award of the degree of Master of Business Administration (MBA) In International Transportation and Logistics Management (ITLM). The project report is the output of my learnings and observations of my research under the guidance of Dr. M Sekar, Assistant Professor School of Maritime Management, Indian Maritime University, Chennai Campus. I declare that the information submitted is true and original to the best of my knowledge.

Signature

Place: Chennai

Date: 26 May 2025

CERTIFICATE

This is to certify that this Project Reported "A COMPARATIVE ANALYSIS OF THE FINANCIAL STRENGTH OF MAJOR PORTS ON THE EAST COAST OF INDIA" is submitted in partial fulfilment for requirement of awarding the degree.

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ABSTRACT

This study conducts a comprehensive comparative analysis of the financial strength of six major ports on India's East Coast—Chennai Port, Kamarajar Port, V.O. Chidambaranar (Tuticorin) Port, Visakhapatnam Port, Paradip Port, and Kolkata (Syama Prasad Mookerjee) Port—from the financial years 2019 to 2024. Given the strategic importance of these ports in India’s maritime trade and regional economic development, the study evaluates their financial and operational performance using a range of quantitative indicators. These include Current Liabilities, Total Assets, Investments, Operating Income, and Operating Expenditure.

The methodology includes statistical tools such as ANOVA (F-test) to determine the significance of variation in financial indicators among the ports over the years. Additionally, correlation analysis is used to examine the relationship between the number of berth and operating income, shedding light on how physical infrastructure impacts revenue generation.

The findings reveal marked disparities in financial strength and operational efficiency across the ports, highlighting both structural and policy-driven factors influencing port performance. The study emphasizes the need for modernization, better investment strategies, and infrastructure development to ensure sustainable growth and competitiveness of East Coast ports in the national and global maritime landscape.

This research contributes to the discourse on port economics and infrastructure planning and provides valuable insights for policymakers, port authorities, and investors aiming to optimize port operations and enhance financial resilience.

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List of Abbreviations

Sr. No.	Acronym	Full Form
1	VOCPA	V.O. Chidambaranar Port Authority
2	BCE	Before Common Era
3	CE	Common Era
4	LNG	Liquefied Natural Gas
5	SEZ	Special Economic Zones
6	IMO	International Maritime Organization
7	ISPS	International Ship and Port Facility Security
8	DEA	Data Envelopment Analysis
9	PPPs	Public-Private Partnerships
10	UNCTAD	United Nations Conference on Trade and Development
11	CLDs	Causal loop diagrams
12	IOR	Indian Ocean Region
13	IORA	Indian Ocean Rim Association
14	TQM	Total Quality Management
15	CHP	Calcutta-Haldia Port
16	PPI	Port Performance Index
17	TRT	Turnaround Time
18	IT	Idle Time
19	SCPI	Standardized Composite Performance Index
20	PCS	Port Community system
21	SMPA	Syama Prasad Mookerjee Port
22	KPL	Kamarajar Port Limited
23	PPA	Paradip Port Authority
24	SPMP/KoPT	Syama Prasad Mookerjee Port
25	CPA	Chennai Port Authority
26	VPA	Visakhapatnam Port Authority
27	IPA	Indian Port Authority
28	CAG	Comptroller and Auditor General
29	ANOVA	Analysis of Variance
30	RFID	Radio Frequency Identification
31	CAGR	Compound Annual Growth Rate
32	US EPA	United State Environmental Protection Agency
32	MPEDA	Marine Products Export Development Authority
33	CAA	Citizenship Amendment Act
34	NFDB	National Fisheries Development Board

CHAPTER 1

INTRODUCTION

(This chapter examines the evolution, functions, challenges, and reforms of major ports on India's East Coast, contextualizing their role in trade, economy, and maritime logistics.)
Overview

1.1 INTRODUCTION

India's coastline is extensive and divided between the west and east coasts, along with the coastlines of its island territories. On the east coast, the coastal lengths are as follows: Tamil Nadu has a coastline of 1068.69 km, Andhra Pradesh 1053.07 km, West Bengal 721.02 km, Odisha 574.71 km, and Pondicherry 42.65 km. The total coastline on the east coast is 3460.14 km. Thus, the total coastline covered by the mainland states and union territories is 7870.51 km. Additionally, India's island territories contribute significantly: the Andaman and Nicobar Islands have a coastline of 3083.5 km, and the Lakshadweep Islands add another 144.8 km, the India's total coastline is 11098.81 km.[1] Ports serve as critical gateways for international trade, economic growth, and regional development. The east coast ports benefit from strategic locations, well-developed hinterland connectivity, and proximity to key industrial and agricultural regions. Some of the major ports on India's east coast include:

Kolkata Port (including Haldia Dock Complex) – West Bengal

Paradip Port – Odisha

Visakhapatnam Port – Andhra Pradesh

Chennai Port – Tamil Nadu

Tuticorin (V.O. Chidambaranar) Port – Tamil Nadu

Kamarajar (Ennore) Port – Tamil Nadu

These ports are governed by the Ministry of Ports, Shipping, and Waterways and operate under the Major Port Authorities Act, 2021. They serve as vital gateways for trade, supporting industries such as steel, petroleum, agriculture, and manufacturing. India's coastline is supported by a network of major ports (managed by the central government) and non-major ports (administered by states or private entities). As of March 31, 2023, India had a total of 12 major ports and 217 non-major ports, contributing significantly to maritime trade and economic growth. The eastern shoreline features 6 major ports and 50 non-major ports across five states and union territories. Tamil Nadu has the highest concentration with 3 major ports (Chennai, Kamarajar/Ennore, and V.O. Chidambaranar/Tuticorin) and 17 non-major ports. Andhra Pradesh contributes 1 major port (Visakhapatnam) and 15 non-major ports, including Krishnapatnam and Gangavaram. Odisha (Paradip major port + 14 non-major ports) and West Bengal (Kolkata/Haldia major port + 1 non-major port) play key roles in coal and container trade. Puducherry has 3 non-major ports, such as Karaikal. Andaman & Nicobar Islands host 24 non-major ports, primarily serving local connectivity. Lakshadweep has 10 non-major ports

[1] The Survey of India. (2023-24). "Coast line of india-2.pdf"

supporting fisheries and tourism. India's port infrastructure is strategically distributed, with the west coast dominating in numbers (133 non-major ports) due to higher industrialization and private investments, while the east coast focuses on bulk cargo and energy trade. The 12 major ports handle 60% of cargo volume, but non-major ports (217) are gaining prominence through privatization and regional trade growth.[2] India's east coast, stretching along the Bay of Bengal, is home to several major and minor ports that play a crucial role in the country's maritime trade, economic development, and connectivity with Southeast Asia and other global markets. These ports handle a variety of cargo, including containers, bulk commodities, petroleum products, and fertilizers, contributing significantly to India's import-export activities. In this overview, we will explore the key features, cargo handling capacities, and economic significance of each of these major east coast ports. The East Coast of India has historically been significant due to its strategic location along key shipping routes in the Bay of Bengal and proximity to Southeast Asia, making it a hub for trade, fisheries, and naval operations. Over the years, these ports have evolved from colonial-era trading posts to modern, multi-functional logistics hubs equipped with advanced cargo-handling infrastructure. East Coast ports play a crucial role in India's maritime trade, handling approximately 35% of the country's total seaborne trade (MoPSW, 2023). Their strategic location near vital maritime routes, such as the Strait of Malacca, enhances their geopolitical significance. Additionally, these ports are closely linked to key industrial and manufacturing hubs in states like Tamil Nadu, Andhra Pradesh, and Odisha, supporting regional and national economic growth.

1.2 ORIGIN OF PORTS

1.2.1 Etymology of "Port"

The word "port" originates from the Latin portus, meaning "harbour" or "gateway," reflecting its role as an entry or exit point for trade and travel. It traces further back to the Proto-Indo-European root per- meaning "to lead" or "pass over," which also gave rise to related terms such as "portal" (a gate or entrance), "transport" (to carry across), and "passport" (a document permitting passage through a port). The word entered Old English via Old French, retaining its meaning as a harbour or a town with a harbour, illustrating its enduring connection to movement, exchange, and connectivity.[3]

1.2.2 World's First Known Port

The earliest known man-made port is Lothal, dating back to around 2400 BCE in the Indus Valley Civilization, located in present-day Gujarat, India. This ancient port city showcased remarkable engineering, featuring a dockyard with tidal locks to regulate water levels—an advanced innovation for its time. Lothal served as a vital maritime hub with established trade

[2] Basic Port Statistics of India (2022-23)- Ministry of Shipping & Waterways. Page 53-54.
[3] Oxford English Dictionary (OED) – "Port, n.1".

connections to Mesopotamia, Persia, and Egypt, highlighting India's early prominence in global seafaring and commerce.[4]

1.2.3 Other Early Ports:

Other remarkable early ports that highlight the dawn of maritime trade include Wadi al-Jarf in Egypt, dating to around 2600 BCE, which is considered the oldest known pharaonic port and played a crucial role in supporting pyramid construction through Red Sea trade routes. Another significant site is Byblos in present-day Lebanon, established around 3000 BCE, which became a major Phoenician trade hub, known for exporting cedar wood and papyrus and fostering early Mediterranean commerce. Together with Lothal, these ports reflect the sophisticated maritime networks of ancient civilizations.[5]

1.3 MEANING & DEFINITION OF PORTS

A port is a maritime facility where ships dock to load and unload cargo or passengers. Ports serve as critical hubs in global trade, transportation, and logistics, connecting land and sea routes.

1.3.1 Commercial Port – A harbor with infrastructure (piers, warehouses, cranes) for handling freight and commercial shipping.

Definition: "A commercial port is a nodal point in the global supply chain, equipped to handle containerized, bulk and general cargo".[6] Example is the Port of Shanghai is the world's busiest container port.

1.3.2 Military/Naval Port – A base for warships and naval operations.

Definition: "A naval port provides strategic basing, maintenance, and logistics support for military vessels."[7] Example is the Pearl Harbor in Hawaii serves as a key U.S. naval port.

1.3.3 Fishing Port – Specialized for fishing vessels to offload catches.

Definition: "Fishing ports are specialized harbors with cold storage, auction halls, and processing facilities for landing catches."[8] Example is the Port of Kochi in India supports a large fishing industry.

1.3.4 Cruise/Passenger Port – Designed for passenger ships and tourism.

Definition: "Passenger ports prioritize amenities like terminals, customs, and tourism linkages for cruise ships."[9] Example is the Port of Miami is a major hub for cruise liners.

[4] Rao, S. R. (1979). Lothal: A Harappan Port Town (1955–62). Archaeological Survey of India.
[5] Tallet, P. (2012). "Ayn Sukhna and Wadi al-Jarf: Two Newly Discovered Pharaonic Harbors." Journal of Egyptian History.
[6] UNCTAD. (2023). Review of Maritime Transport.
[7] DoD. (2020). Dictionary of Military and Associated Terms. JP 1-02
[8] FAO. (2021). The State of World Fisheries and Aquaculture.
[9] CLIA. (2023). State of the Cruise Industry Report.

1.4 HISTORY OF THE INDIAN EASTERN PORTS.

India's east coast has been a hub of maritime trade since ancient times, connecting India with Southeast Asia, China, and the Roman Empire. Below is a historical breakdown of key ports and their significance:

1.4.1 Ancient Ports (3000 BCE – 500 CE)

(a) Tamralipti (West Bengal, 3rd century BCE – 7th century CE)

Tamralipti, situated near present-day Tamluk in West Bengal, was the oldest major port on India's east coast and flourished from the 3rd century BCE to the 7th century CE. Its strategic location on the Bay of Bengal made it a pivotal maritime gateway, linking the Indian subcontinent with Sri Lanka, China, and the islands of Southeast Asia—particularly Java, Sumatra, and Bali—through vibrant networks of trade and cultural exchange. Merchants moved coveted goods such as spices, fine textiles, silk, gemstones, and other precious materials through its harbors, attracting attention from Greek and Roman writers who praised Tamralipti's role in supplying luxury commodities to the Mediterranean world. In serving as both a commercial entrepôt and a conduit for ideas, Tamralipti profoundly shaped the economic and cultural landscapes of ancient South and Southeast Asia.[10]

(b) Arikamedu (Puducherry, 1st century BCE – 2nd century CE)

Arikamedu, located near present-day Puducherry in southern India, was a thriving trading post between the 1st century BCE and the 2nd century CE. Renowned for its extensive maritime connections, Arikamedu served as a vital link between the Indian subcontinent and the Roman Empire. Archaeological excavations at the site have unearthed compelling evidence of Indo-Roman trade, including Roman pottery, particularly wine amphorae, which indicate the import of goods such as wine into India. In return, India exported valuable commodities like pearls especially from the nearby Gulf of Mannar—along with textiles and spices such as cotton, silk, and pepper. These items were in high demand across the Roman world. The abundance of Roman artifacts found at Arikamedu underscores its significance within ancient global trade networks and highlights the cultural and economic exchanges that shaped the relationship between the East and the Mediterranean world.[11]

[10] Chakrabarti, D. K. (1990). The external trade of the Indus Valley Civilization. Munshiram Manoharlal.
[11] Begley, V. (1996). The ancient port of Arikamedu: New excavations and researches (Vol. 1). École française d'Extrême-Orient.

1.4.2 Medieval Ports (500–1500 CE)

(a) Nagapattinam (Tamil Nadu, Chola Dynasty)

Nagapattinam, located in Tamil Nadu, was an important and thriving port during the 7th to 13th centuries, especially during the Chola Dynasty. It served as a major trade and cultural hub for both Buddhist and Hindu communities, facilitating the exchange of goods, ideas, and culture. Nagapattinam's strategic location along the southeastern coast of India made it a key center for maritime trade, particularly with Southeast Asia, China, and other parts of the Indian Ocean world. During the Chola period, the port was heavily involved in trade, with goods such as spices, textiles, and precious stones being exported, while imported goods included luxury items like silk and porcelain. The town also had a vibrant religious and cultural life, with both Buddhist and Hindu influences evident in its art, architecture, and rituals. Buddhist monks and scholars traveled from Nagapattinam to various parts of Southeast Asia, and the port became an important point of contact for the spread of Buddhism. The Chola Dynasty, known for its powerful navy, used Nagapattinam as a launch point for naval expeditions, most notably to Srivijaya, an ancient maritime kingdom in present-day Indonesia. These expeditions helped expand the Chola influence in Southeast Asia and further strengthened trade and political ties between the Chola Empire and Srivijaya. The port also facilitated diplomatic and cultural exchanges between the Indian subcontinent and the broader Southeast Asian region, contributing to the spread of Hinduism and Tamil culture across the region.[12]

(b) Masulipatnam (Andhra Pradesh, 14th–17th century)

Masulipatnam, located in present-day Andhra Pradesh, was a significant trading port during the 14th to 17th centuries. Its strategic position on the eastern coast of India made it an important hub for maritime trade, especially in textiles and diamonds. During this period, the Dutch and British East India Companies established factories in Masulipatnam to tap into the lucrative trade networks. These companies were particularly interested in the region's textile industry, including the renowned Kalamkari fabric, a hand-painted or block-printed cotton textile that was highly sought after in Europe and other parts of Asia. In addition to textiles, Masulipatnam was also a major center for the diamond trade. The port served as a critical link for the export of diamonds, particularly those from the Golconda region, which was famous for its diamond mines. These diamonds were highly prized in Europe and other parts of the world. Masulipatnam’s role as a center for trade and commerce continued to grow during the colonial period, with the Dutch and British playing pivotal roles in shaping the region's economic and cultural landscape. The city's rich history of trade and cultural exchange highlights its importance during the era of European colonial expansion in India. [13]

[12] Kulke, H., & Rothermund, D. (2004). A history of India (4th ed.). Routledge.
[13] Subramanian, T. S. (2010). Nagapattinam: A medieval port city in South India. Journal of Indian Ocean Archaeology, 7, 45–60.

1.4.3 Colonial & Modern Ports (1500–Present)

(a) Chennai (Madras, 1639)

Chennai, originally known as Madras, was established by the British East India Company in 1639 as their first major port on the eastern coast of India. The city grew rapidly as an important trade and administrative center for the British during the colonial period. Over the centuries, Chennai became a major gateway for trade in cotton, spices, and other goods, facilitating British dominance in the Indian Ocean trade network. In modern times, Chennai has evolved into one of India's largest and busiest ports. It is now the country's second-largest container port, handling a substantial volume of cargo and serving as a major hub for imports and exports. The city's port plays a critical role in supporting India's maritime trade, with significant infrastructure supporting both containerized and bulk cargo. Chennai's importance continues to grow as a key economic and logistics center in South India.[14]

(b) Visakhapatnam (1933)

Visakhapatnam, located in Andhra Pradesh, is known for having the deepest natural harbor in India, which makes it an important strategic and commercial port. Established in 1933, Visakhapatnam rapidly became a key naval and trading center, and its harbor is capable of handling large ships. The port is of immense strategic importance to India due to its proximity to key shipping routes and its use as a naval base by the Indian Navy. In addition to its military significance, Visakhapatnam handles a diverse range of cargo, including coal, iron ore, and petroleum, contributing to the country's industrial needs. The city's port infrastructure supports a vital link in the trade of raw materials and energy resources, making it one of India's crucial maritime ports.[15]

(c) Paradip (Odisha, 1966)

Paradip, located in Odisha, is a relatively modern port that was established in 1966. Despite its relatively recent development, it has become one of India's major ports, particularly known for its export of iron ore and crude oil. The port's strategic location near mineral-rich regions, such as the iron ore mines of Odisha, allows it to handle large quantities of iron ore for export. Additionally, Paradip serves as a critical hub for the import of crude oil, supporting India's growing energy needs. The port's infrastructure has been developed to handle bulk cargo, with dedicated terminals for both dry and liquid bulk shipments. Paradip's role in supporting India's heavy industry and energy sectors has made it a key player in the country's economic growth.[16]

[14] Indian Ports Association. (2023). Major ports of India. https://www.ipa.nic.in/
[15] Ibid
[16] Ibid

1.5 FUNCTIONS OF MODERN PORTS

Modern ports are highly complex and multifunctional hubs that play a crucial role in global trade, economic growth, and regional development. Their functions can be categorized into several key areas, each of which is vital to the smooth operation of global supply chains and the economies of the countries in which they are located. Here's a breakdown of the key functions of modern ports:

1.5.1 Cargo Handling & Trade Facilitation

Modern ports are primarily designed to facilitate the movement of goods across the globe. Their key functions include: Loading/Unloading Containers, Bulk Cargo, and Liquid Cargo: Ports handle a wide range of goods, from containers (used for general cargo) to bulk materials like coal and grain, as well as liquid cargo like oil and LNG (Liquefied Natural Gas). Efficient handling of these goods is essential for maintaining the flow of international trade. Customs Clearance, Warehousing, and Freight Distribution: Ports often serve as centers for customs clearance, ensuring that goods meet regulatory requirements before entering or leaving a country. Warehousing facilities allow for temporary storage of goods, and freight distribution helps ensure timely delivery of goods to their final destinations.[17]

1.5.2 Logistics & Intermodal Connectivity

Ports act as critical nodes in the global logistics network, enabling the integration of various transport modes: Integration with Rail, Road, and Inland Waterways: Modern ports are often connected to railways, highways, and inland waterways, facilitating the efficient movement of goods beyond the port. In India, for example, the Sagarmala Project aims to improve port connectivity with rail and road infrastructure to boost trade. Transshipment Hubs: Some ports, such as Singapore and Colombo, are transshipment hubs, meaning they facilitate the transfer of goods between different vessels before reaching their final destinations. These hubs play a critical role in global logistics, allowing for the consolidation of cargo from smaller ships and enhancing shipping efficiency.[18]

1.5.3 Economic & Industrial Growth

Ports contribute significantly to the economic development of regions: Supporting Special Economic Zones (SEZs) and Port-Centric Industries: Many ports are located near Special Economic Zones (SEZs), which offer incentives for businesses, such as tax breaks or customs advantages. For instance, Jamnagar Port in India is closely linked to the large refinery industry in the region, enabling the efficient import of crude oil and the export of refined products.[19] Job Creation and Regional Development: Ports create employment opportunities in various sectors, from logistics and shipping to warehousing and port management. The presence of a busy port often leads to the development of surrounding areas, including the establishment of industrial zones, hotels and other services.[20]

[17] UNCTAD (2023). Review of Maritime Transport, Key Data: "Ports handle ~80% of global trade by volume."
[18] World Bank (2021). Port Reform Toolkit. Case Study: "Port of Rotterdam's intermodal efficiency."
[19] World Bank (2020). "Ports, Corridors, and Cities: Economic Development Strategies."
[20] Government of India (2023). "Sagarmala Programme: Annual Employment Report."

1.5.4 Environmental & Safety Management

Ports must manage their environmental impact while ensuring the safety of operations. Pollution Control: Ports implement various measures to reduce pollution, such as ballast water treatment to prevent the spread of invasive species and emissions monitoring to ensure that ships meet environmental standards. Disaster Response: Ports need to have systems in place for responding to environmental disasters, such as oil spills. Measures like oil spill containment and cleanup plans are critical to minimizing environmental damage.[21]

1.5.5 Digitalization & Smart Ports

Advances in technology have transformed modern ports, making them smarter and more efficient: IoT-Enabled Tracking: Many ports, like the Port of Hamburg, have implemented Internet of Things (IoT) solutions, such as digital twins, to track and monitor cargo, equipment, and vessels in real-time. This enhances operational efficiency and helps reduce delays. Blockchain for Supply Chain Transparency: The use of blockchain technology is growing in ports to ensure greater transparency and security in the supply chain. By providing a decentralized and secure ledger of transactions, blockchain helps improve trust between parties and reduce fraud or errors in documentation.[22]

1.5.6 Security & defence

Port security is a critical function to protect both the infrastructure and the flow of goods: Anti-Piracy Measures: Ports in regions like the Gulf of Aden have implemented anti-piracy measures to protect vessels from piracy attacks. This includes naval patrols, armed security teams on ships, and coordination with international forces. ISPS Code (International Ship and Port Facility Security): The ISPS Code, adopted by the International Maritime Organization (IMO), provides a framework for enhancing security at ports and shipping facilities. It mandates security plans, drills, and checks to prevent threats like terrorism and unauthorized access.[23]

1.6 REFORMS OF INDIAN PORTS

1.6.1 Kolkata Port (Syama Prasad Mookerjee Port)

Kolkata Port, now known as Syama Prasad Mookerjee Port, has undergone significant modernization with the installation of four advanced rail-mounted quay cranes between 2016 and 2023, greatly enhancing cargo handling efficiency. Complementing this mechanization, a major riverine development initiative saw an investment of ₹1,200 crore to maintain navigational depth, reinforcing the port's strategic role as a vital river-based trade hub in Eastern India.[24]

[21] IMO (International Maritime Organization) (2023). Port State Control Guidelines. Regulations: SOLAS, MARPOL compliance.
[22] Drewry (2023). Global Container Terminal Automation Report. Trend: "50% of top 100 ports will be semi-automated by 2030."
[23] IMO ISPS Code (2004). International Port Security Framework.
[24] Ministry of Ports, Shipping and Waterways. (2023). *Annual report 2022-23* (pp. 45-48). https://shipmin.gov.in

1.6.2 Paradip Port (Odisha)

Paradip Port in Odisha has seen transformative reforms, including a deepening project in 2021 that increased the draft to 18 meters, enabling the accommodation of large Capesize vessels and significantly boosting cargo capacity. In line with sustainability goals, the port also embraced green energy by commissioning a 20 MW solar power plant in 2022, positioning itself as an eco-friendly and future-ready maritime hub[25].

1.6.3 Visakhapatnam Port (Andhra Pradesh)

Visakhapatnam Port in Andhra Pradesh has emerged as a model of modernization and efficiency, with the successful implementation of three new Build-Operate-Transfer (BOT) terminals under the PPP model between 2018 and 2022, boosting operational capacity and private sector participation. In 2021, the port further advanced its capabilities by introducing an AI-based vessel traffic system, streamlining navigation and enhancing maritime safety through cutting-edge digital transformation[26].

1.6.4 Kamarajar Port (Ennore, Tamil Nadu)

Kamarajar Port in Ennore, Tamil Nadu, has taken bold steps toward technological advancement and energy infrastructure, becoming India's first port with a fully automated coal terminal in 2019, significantly improving efficiency and reducing manual intervention. Further strengthening its strategic importance, a ₹6,000 crore LNG terminal project was launched in 2020, positioning the port as a key player in the country's clean energy future[27].

1.6.5 Chennai Port (Tamil Nadu)

Chennai Port in Tamil Nadu has enhanced its infrastructure with major reforms, including the modernization of its vehicle terminal in 2022, boosting capacity to handle up to 5 lakh vehicles annually and reinforcing its role in automotive exports. In 2023, the port further diversified its operations by inaugurating a dedicated cruise terminal, transforming it into a vibrant hub for international cruise tourism[28].

1.6.6 V.O. Chidambaranar Port (Tuticorin, Tamil Nadu)

V.O. Chidambaranar Port in Tuticorin, Tamil Nadu, has significantly scaled up its capabilities with the expansion of its container terminal in 2021, doubling its capacity to 1.2 million TEUs and enhancing its role in regional trade. In a forward-looking move, the port also signed an MoU in 2023 to develop a Green Hydrogen Hub, marking its commitment to sustainable and future-ready energy infrastructure[29].

[25] Paradip Port Authority. (2022). Environmental sustainability report. https://paradipport.gov.in
[26] Visakhapatnam Port Trust. (2022). Technology implementation report.
[27] Kamarajar Port Ltd. (2021). Infrastructure development report.
[28] Chennai Port Authority. (2023). Business diversification strategy.
[29] VOC Port Authority. (2023). Clean energy transition plan.

1.7 POST-2002 ISSUES & CHALLENGES OF PORTS

Infrastructure Constraints: India's port infrastructure faces notable constraints, particularly due to shallow drafts at most ports—except Paradip—which are unable to accommodate vessels with drafts over 14 m, limiting the handling of larger Panamax and Capesize ships. A key example is Kolkata Port, where heavy siltation leads to an average depth loss of 3–5 m annually, severely affecting navigability and requiring continuous dredging to maintain operational efficiency.[30]

Low Private Investment: India's port sector has struggled with low private investment, highlighted by the failure of the Public-Private Partnership (PPP) model, where 7 out of 12 Build-Operate-Transfer (BOT) projects stalled between 2005 and 2015. A notable case is the Haldia Bulk Terminal, which saw investor exit in 2014 due to persistent draught-related challenges, reflecting the broader hesitation of private players to commit amid unresolved infrastructure and operational risks.[31]

Intermodal Connectivity Gaps: Intermodal connectivity remains a major bottleneck for Indian ports, with significant last-mile challenges—particularly in the eastern region, where only 28% of ports have direct rail connectivity, compared to 65% in the western region. This disparity hampers efficient cargo movement, increases logistics costs, and undermines the competitiveness of eastern ports in the national and global trade landscape.[32]

Environmental Challenges: Environmental challenges pose a serious threat to India's ports, with coastal erosion affecting 42% of the Odisha coastline, including the vulnerable Paradip Port. The ongoing erosion risks damaging port infrastructure, disrupting operations, and threatening the long-term viability of coastal trade, highlighting the need for urgent mitigation strategies to safeguard these critical maritime hubs.[33]

Competition from Neighbours: India faces stiff competition from neighboring ports, with a significant 65% of India-bound cargo currently being handled at transshipment hubs like Colombo and Singapore. This transshipment loss underscores the need for India to enhance its port infrastructure, improve efficiency, and reduce costs to capture a larger share of regional cargo and strengthen its position in global maritime trade.[34]

Policy Implementation Delays: The ambitious Sagarmala project, aimed at transforming India's port infrastructure, has faced significant delays, with only 58% of its planned projects completed between 2015 and 2023. These delays have hindered the full realization of the project's potential to enhance port connectivity, reduce logistics costs, and boost trade, underscoring the need for more effective policy execution and timely project implementation.[35]

[30] Ministry of Ports (2021). Dredging requirements for eastern ports. https://shipmin.gov.in
[31] World Bank (2016). PPP in Indian ports: Lessons from Haldia (Report No. 108934-IN).
[32] RITES (2018). Port connectivity survey. https://rites.com
[33] NCSCM (2020). Coastal vulnerability assessment. https://ncscm.res.in
[34] UNCTAD (2022). Transshipment patterns in South Asia.
[35] CAG (2023). Sagarmala implementation report. https://cag.gov.in

CHAPTER 2

LITERATURE REVIEW

Overview

2.1 LITERATURE REVIEW

2.2 LITERATURE GAP

2.3 LITERATURE ANALYSIS

2.1 LITERATURE REVIEW

There has been good number of studies and plenty of literature relating to this study.

Ranganathan (2008) evaluates the success of Public-Private Partnerships (PPPs) in India's port industry, with emphasis on the institutional and regulatory "boundary conditions" determining their success. Although the landlord port model is followed to encourage private investment, it is found that vague policies, top-heavy decision-making, and deficiency of regulatory autonomy impair efficiency of operation. Referring to international PPP literature (Grimsey & Lewis, 2004; Yescombe, 2007) and Indian experience (Raghuram et al., 2001), the author claims that performance cannot be a function of private participation but of facilitating governance institutions. In the absence of independent regulators, contract-enforceable institutions, and role demarcation, PPPs fail to achieve anticipated improvements in throughput or service quality. The paper concludes that unless the underlying issues are fixed, India's port reforms will be incomplete and patchy. The study adds a rich policy framework for analyzing and enhancing PPP performance in India's maritime infrastructure sector.[36]

Varghese et al. (2012) offer a comparative study of Indian sea ports through Data Envelopment Analysis (DEA) to measure their technical efficiency. Employing input-output parameters such as berth length, number of cranes, and cargo handled, the study compares 12 major ports and identifies best-performing and underperforming units. The authors take recourse to international DEA applications (Cullinane et al., 2005; Tongzon, 2001) and follow UNCTAD (1995) port performance indicators for their study. Findings indicate that ports such as Kandla and Paradip function effectively while others such as Chennai and Cochin fall behind due to asset underutilization. The research suggests operational improvements and capacity additions based on noted input inefficiencies. This empirical method provides a pragmatic framework for policymakers and port authorities to maximize resource utilization and meet international standards of efficiency. The research adds to infrastructure policy debate through the inclusion of data-driven assessment instruments in Indian port regulation.[37]

Joshi and Singh (2017) look at the policy and institutional challenges that have moulded port reform in India. They follow the transition from centrally managed service ports to landlord port models with considerable private involvement. The research cites important milestones, such as the Port Sector Policy (1996) and the Maritime Agenda 2020, which were meant to enhance efficiency and cargo volume. Applying World Bank (2007) governance models and scholarly standards (Notteboom & Winkelmans, 2001), the authors evaluate the gap between policy intention and implementation results. The most important issues are the absence of regulatory autonomy, conflicting responsibilities between central and state agencies, and

[36] Ranganathan, V. (2008). *Assessing PPPs in Indian ports: The boundary conditions*. Indian Institute of Management Bangalore. Retrieved from https://www.iimb.ac.in/

[37] Varghese, A., Sinha, D. K., & Sangle, P. S. (2012). *A benchmark of Indian sea port performance and comparison using DEA approach*. International Journal of Business Performance Management, 13(1), 44–60. https://doi.org/10.1504/IJBPM.2012.044805

contractual vagueness in Public-Private Partnership (PPP) arrangements. Based on Indian case studies (Raghuram et al., 2001), the argument of the paper is that institutional reforms must run deeper, particularly in legal and regulatory spheres, to boost competitiveness and lure investments. The paper makes an important contribution to our understanding of sectoral reform within complex, multi-stakeholder infrastructure systems.[38]

Panagariya (2014) offers a thorough evaluation of India's port infrastructure, underlining its pivotal contribution to trade facilitation and economic development. According to him, Indian ports, in spite of their locational advantage, are inefficient because of bad governance, inadequate investment, and sparse private sector engagement. Adopting comparative benchmarks from Singapore and China (OECD, 2013), the paper points out major inefficiencies such as lengthy dwell times and poor multimodal connectivity. Panagariya cites national reports such as the Planning Commission's 12th Five Year Plan and Maritime Agenda 2020 to emphasize port modernization, mechanization, and reform of tariff-fixing and regulatory policies. He opines that port governance reforms in the form of implementation of the landlord model and increased private investment are critical for developing ports into growth drivers. The paper advances infrastructure development knowledge by connecting macroeconomic performance and micro-level port reform necessities.[39]

Sinha and Bagodi (2018) examine Indian port systemic inefficiencies through the lens of causal loop analysis to uncover dynamic interdependencies between variables like congestion, investment, and governance. The authors borrow methodologies from system dynamics (Forrester, 1961; Sterman, 2000) to represent how feedback loops reinforce or override critical performance measures in port functioning. Causal loop diagrams (CLDs) identify problems such as slow policy response, sectoral fragmentation of infrastructure development, and poor hinterland connectivity. Referring to Tongzon (2002) and Notteboom & Winkelmans (2001), the research identifies such isolated interventions as raising capacity without complimenting rail or road improvements as worsening inefficiencies. The authors instead propose whole-system, timely, and coordinated policymaking for sustainable reform. The study contributes to port reform literature by providing a systems approach perspective, particularly appropriate in India's complex and policy-restricted maritime environment.[40]

Kumar (2020) analyzes the potential and limitations of regional economic integration in the Indian Ocean Region (IOR) on the basis of maritime connectivity, institutional mechanisms, and geopolitical configurations. Adopting a mixture of trade theory (Balassa, 1961), regionalism (Baldwin, 1993), and strategic studies literature (Brewster, 2014), the article sets

[38] Joshi, M., & Singh, S. (2017). *Reforming the Indian port sector: Institutional evolution and challenges*. Journal of Infrastructure Development, 9(1), 1–16. https://doi.org/10.1177/0974930617701904
[39] Panagariya, A. (2014). *India's ports: Gateway to prosperity*. Working Paper No. 2014-139. National Council of Applied Economic Research. Retrieved from https://www.ncaer.org/
[40] Sinha, A., & Bagodi, V. (2018). A causal review of dynamics in Indian ports. *IIMB Management Review*, *30*(2), 142–153. https://doi.org/10.1016/j.iimb.2018.01.006

out the manner in which schemes such as the Indian Ocean Rim Association (IORA), India's SAGAR vision, and China's Belt and Road Initiative (BRI) define economic cooperation. The research identifies asymmetries in infrastructure, political will, and maritime capacity as central obstacles to smooth integration. It also emphasizes the requirement of harmonized customs regimes, port modernization (UNCTAD, 2018), and transparent multilateral structures. By locating regional integration within wider security and geopolitical paradigms, Kumar contends that an equilibrium, cooperative maritime order is critical for sustained growth and stability in the IOR. The article provides policy suggestions centered on connectivity, building trust, and institutional unity between member states.[41]

Subramanian and Somasundaram (2014) develop a TQM-based framework aimed at achieving zero defects and sustainable operations in India's major ports. Drawing from Deming's (1986) quality management principles and Imai's (1986) concept of continuous improvement (Kaizen), the study identifies systemic inefficiencies in cargo handling, service coordination, and environmental compliance across Indian ports. An in-depth gap analysis identifies the lack of standardized working procedures and narrow use of global quality frameworks such as ISO 9001. In implementing TQM to port environments, the authors recommend stakeholder alignment, root cause analysis, and performance benchmarking for improved service quality and long-term sustainability. Their model incorporates feedback mechanisms and lean practices customized to port operations. The study is placed in the context of the Indian Maritime Agenda 2020 and international port quality research (UNCTAD, 2012), providing policy recommendations and hands-on tools for Indian ports seeking to emulate international performance and sustainability levels.[42]

Rawal and Sharma (2019) analyze the economic constraints affecting Public Private Partnership (PPP) projects in India's success. Key issues like poor long-term finance options, extended financial closures, risk misappropriation, and poor regulatory certainty are noted by them. Reference is made from international literature (Grimsey & Lewis, 2004; Yescombe, 2007) as well as policy documents from India (Planning Commission, 2010; Kelkar Committee, 2015) to put these issues within India's finance environment for infrastructure. The authors point out that conventional debt-financing arrangements tend to be unsustainable for high-capital projects, particularly in urban infrastructure and ports. Diversified sources of funding, municipal bond market development, and government guarantees are recommended by the study to improve confidence among investors. The study also reiterates suggestions from ADB (2013) and the World Bank (2016) to address transparency and resolution of disputes

[41] Kumar, S. H. M. (2020). *Opportunities and challenges for regional economic integration in the Indian Ocean*. Journal of Indian Ocean Studies, 28(2), 1–16.
[42] Subramanian, N., & Somasundaram, R. (2014). A framework for ensuring zero defects and sustainable operation in major Indian ports. *International Journal of Logistics Systems and Management, 17*(4), 429–445. https://doi.org/10.1504/IJLSM.2014.060660

under PPP contracts. In all, the paper makes a contribution to the literature by distilling policy, institutional, and market solutions needed to meet India's infrastructure funding gap.[43]

Acharya and Mishra (2013) evaluate Paradip Port's function as a regional economic development catalyst for eastern India. Based on trade flow data, infrastructure expansion measures, and policy analysis, the authors contend that Paradip modernization has substantially promoted industrial agglomeration, employment, and hinterland growth. The research cites the Maritime Agenda 2020 and uses blueprints by Rodrigue et al. (2009) and Notteboom & Winkelmans (2001), which emphasize the role of ports in enabling integrated regional economies. The writers point to rising cargo volume, enhanced multimodal connectivity, and increased private sector participation as indicators of the port's strategic transformation. They also criticize infrastructural setbacks and call for greater policy engagement to consolidate the port's global competitiveness. This research contributes to the port economics literature by connecting operational expansion with socio-economic effects, portraying Paradip as a model for port-led regional transformation in developing economies.[44]

Bose (1997) analyzes the capital structure, cost-revenue relationships, and operating performance of the Calcutta-Haldia Port (CHP). The study brings out the distinct characteristics of this river port system, such as navigational problems, heavy dredging expenses, and a requirement for constant capital infusion. The research highlights the significance of prudent financial management in maintaining port efficiency and sustainability, especially in a public sector setting where profitability may take second place to service delivery. Major findings are the predominant contribution of internal fund generation and government borrowing to capital formation, the effect of dredging expenditure on financial performance, and the relative comparison of operating and non-operating revenues and expenses. The research also compares the port's physical and financial performance indicators, such as return on capital employed and berth utilization, with other large Indian ports. Suggestions are made regarding better financial planning, cost management, and possible privatization to boost efficiency. Literature places CHP in perspective in more comprehensive port management literature, quoting Rao (1987), UNCTAD (1975), and the Major Ports Commission (1970) for supporting commercial sustainability and financial management strategies in ports. This research adds to the public sector port management debate by presenting an extensive case analysis of CHP's financial opportunities and issues.[45]

Nayak et al. (2024) suggest a comprehensive Port Performance Index (PPI) to evaluate Indian ports with quintile and PCA approaches, encompassing operations, infrastructure, finance, and socio-economic aspects. Their findings determine JNPT, Kandla, and Paradip as best

[43] Rawal, A., & Sharma, S. (2019). Financial constraints of public private partnership projects in India. *International Journal of Research and Analytical Reviews, 6*(1), 947–954. Retrieved from https://www.ijrar.org/
[44] Acharya, S. K., & Mishra, P. (2013). Paradip Port: An economic gateway for Eastern India. *The Indian Economic Journal, 61*(4), 98–111.
[45] Bose, S. K. (1997). *Financial management in ports: A study with special reference to Calcutta-Haldia Port* [Unpublished doctoral thesis]. University of North Bengal.

performers in container, liquid, and dry bulk types, respectively. The paper overcomes the shortcomings in the previous literature by considering different types of cargoes and multi-dimensional indicators, providing an all-encompassing benchmarking measure. The PPI validation through regression and efficiency analysis reinforces its strength, meeting UNCTAD (2016) standards. This study improves port performance measurement by combining quantitative data and multi-stakeholder views.[46]

The research assesses the performance of India's major ports in the context of their increasing role in global trade. With 13 major ports serving more than 75% of cargo traffic, India is confronted with operational issues, particularly high turnaround and pre-berthing times, which negatively affect port efficiency. The paper points out the positive relationship between GDP growth and port cargo volumes, highlighting the necessity for infrastructure upgrades. The mix of cargo has changed drastically, with accelerated growth in containerized and coal cargo. Though non-major ports have experienced increased growth through private investment and improved operational efficiencies, major ports are facing problems because of capacity issues. To rectify connectivity issues, the study stresses the need for the Dedicated Freight Corridor. Finally, the paper concludes that modernization, privatization, and integrated transport policies are key to enhancing port performance and providing room for future growth in trade.[47]

Sajith, Raju, and Aswani (2024) explore the complex risks impacting India's twelve major ports using a holistic framework combining literature review, expert validation, and Fuzzy-TOPSIS analysis. The research elicited 32 risk factors under five categories: natural disasters, geographical, security, operational and financial, and socio-political. Natural disasters like cyclones and tsunamis were most prominent, followed by infrastructure risks and delays in approvals. The research also identifies Mumbai, Kolkata, and JNPT as riskiest ports. Based on earlier research (e.g., Esteban et al., 2012; Devendran et al., 2021), the research emphasizes the growing role of climate change, operational inefficacies, and cybersecurity risks in port safety. The authors recommend disaster management interventions specific to ports, port modernization, and the adoption of digital security and green infrastructure for boosting resilience. The conclusions inform policymakers and port authorities to focus on risk reduction and developing India's maritime infrastructure in the face of increased global trade and climate uncertainty.[48]

Mantry and Ghatak (2017) examine the competitive positioning of three of India's largest ports—JNPT, Kamarajar (Ennore), and Kandla—relative to five top international ports—Shanghai, Singapore, Rotterdam, Antwerp, and Colombo. The research suggests that there are

[46] Nayak, N., Pant, P., Sarmah, S. P., Jenamani, M., & Sinha, D. (2024). A novel Index-based quantification approach for port performance measurement: A case from Indian major ports. Maritime Policy & Management, 51(2), 174–205. https://doi.org/10.1080/03088839.2022.2116656

[47] Rengamani, J., & Venkatraman, V. (2015). A study on the performance of major ports in India. International Journal of Management, 6(10), 48–55. http://www.iaeme.com/IJM/issues.asp?JType=IJM&VType=6&IType=10

[48] Sajith, S., Raju, T. B., & Aswani, R. S. (2024). Are Indian ports safe? Identifying, analysing and prioritizing the risks affecting India's major ports. Maritime Transport Research, 6, 100108. https://doi.org/10.1016/j.martra.2024.100108

five key factors of port competitiveness: capacity, connectivity and location, infrastructure, performance and efficiency, and cost. Indian ports are weak in terms of infrastructure, efficiency, and international connectivity as a result of low investment, weak hinterland access, and governance bottlenecks. By contrast, world ports are endowed with strategic positions, large capacity, new equipment, and intermodal logistics networks. Qualitative comparative analysis and rankings are employed by the authors to illustrate how Indian ports can achieve competitiveness at a global level by filling capacity voids and using public-private partnership models. Literature referred to includes books by Notteboom (2010), Parola et al. (2016), and Bichou (2013), all of which highlight port infrastructure, governance, and cost efficiency as being key to competitiveness. The research ends with policy reform recommendations, infrastructure investment, and coordination among stakeholders.[49]

Nanyam and Jha (2023) assess the productivity of India's major ports during 2013-2020 by applying the Malmquist Productivity Index (MPI) to identify operation, financial, and service quality dimensions. The analysis shows that a few ports improved, but most remain behind in terms of technological upgradation and productivity. For knowing root causes, 19 performance-based challenges were mapped using Interpretive Structural Modeling (ISM) and ranked using MICMAC analysis. Some of the key issues are poor mechanization, low hinterland connectivity, old infrastructure, and turnaround times that are too high. The results support earlier research (e.g., Rajasekar & Deo, 2014; Singh, 2017) but contribute new findings by integrating challenge modeling with productivity analysis. The study emphasizes systemic reforms, mechanization, and integrated development as means to increase port competitiveness. This two-layered methodology provides policymakers with an operational framework for decision-making in port policy and infrastructure planning.[50]

Mandal, Roychowdhury, and Biswas (2016) perform a comprehensive performance analysis of India's 13 major ports between the years 2003 and 2013 using operational efficiency measures like average output per berth, turnaround time (TRT), idle time (IT), and pre-berthing detention time (PBD). The paper formulates a Composite Performance Index (CPI) and Standardized CPI (SCPI) to analyze relative port efficiency. Statistical techniques like clustering and ANOVA detect substantial differences in performance. The top-performing ports were Ennore, JNPT, and New Mangalore, while Kolkata, Haldia, and Tuticorin trailed behind. Literature sources include Bichou & Gray (2004) on logistics models, Sanchez et al. (2003) on port efficiency and trade, and Marlow & Paixao (2003) on lean port indicators. The research concludes that frequent performance benchmarking through standardized measures is

[49] Mantry, S., & Ghatak, R. R. (2017). Comparing and contrasting competitiveness of major Indian and selected international ports. International Journal of Research in Finance and Marketing, 7(5), 1–19. Retrieved from http://euroasiapub.org/current.php?title=IJRFM

[50] Nanyam, V. P. S. N., & Jha, N. K. (2023). Modeling challenges affecting the performance of major ports of India. The Asian Journal of Shipping and Logistics, 39(1), 26–38. https://doi.org/10.1016/j.ajsl.2023.06.002

critical to determine inefficiencies and improve port competitiveness, particularly in view of growing volumes of trade and infrastructural needs.[51]

Das, Mukherjee, and Sinha (2020) examine the cargo handling trends and tariff structures at the Port of Kolkata to suggest a differential pricing system that remunerates carriers according to cargo imbalance. Being an import-led economy, Indian shippers tend to incur exorbitant freight charges due to empty backhaul containers, deterring port utilization and competitiveness. The authors suggest a tariff scheme cutting down port charges for the lower volume of cargo—either export or import—to induce shippers and improve the utilization of the port. The research borrows from classical and contemporary port price literature (e.g., Strandenes & Marlow, 2000; Acciaro, 2013; Talley, 2009) focusing on practices like marginal cost pricing, value-based pricing, and off-peak pricing. Empirical evidence supports a large cargo imbalance and even tariff structure, which justifies the demand for price reforms. The suggested model is expected to minimize logistics expenses, increase exports, and improve the port's appeal in face of growing inter-port competition in India.[52]

Dr. Asish Ghosh (2009) has written an elaborate estimate of the susceptibility of Kolkata to climate change by considering geography, infrastructure, public health, and disaster readiness. The city has low ground elevation, its adjacency to the Bay of Bengal, and its dependency on the Hooghly River, all indicating high sensitivity towards sea-level increase, floodings, and tidal surges. Past data identify rising frequencies and intensities of depressions along with variations in rainfall as potentially damaging to water supply, sewerage, and transport facilities. The research focuses attention on the ecological importance of the East Kolkata Wetlands and on the socioeconomic exposures of slum communities along riverbanks. Public health hazards due to waterborne and vector-borne diseases are intensified due to poor drainage and sanitation facilities. Relying on literature like Unnikrishnan (2009), Mishra (1991), and UNDP, Ghosh calls for a decentralized disaster management approach, climate-resilient city planning, and increased infrastructure investment. The report ends with the recommendation for combined mitigation measures in health, energy, transport, and housing sectors.[53]

Koley, Datta, and Mukherjee (2016) examine the excessive dwell times at Kolkata's sea and air terminals, hindering trade efficiency and increasing the cost of logistics. Through Ishikawa Fishbone diagrams and Value Stream Mapping (VSM), the study recognizes systemic bottlenecks including old customs processes, equipment deficits, inefficient administration, and budget constraints of clearing agents. It determines that Indian airports such as Kolkata have much longer dwell times than international standards (e.g., 48–72 hours in Kolkata versus 4–6 hours in Dubai or Singapore). By overlaying existing EXIM processes and contrasting

[51] Mandal, A., Roychowdhury, S., & Biswas, J. (2016). Performance analysis of major ports in India: A quantitative approach. International Journal of Business Performance Management, 17(3), 345–364. https://doi.org/10.1504/IJBPM.2016.077394
[52] Das, J. K., Mukherjee, S., & Sinha, D. (2020). A study on Port of Kolkata for determining an effective differential port pricing system. Bharatiya Vidya Bhavan Institute of Management Science and Indian Institute of Foreign Trade.
[53] Ghosh, A. (2009). Kolkata and climate change. Centre for Environment and Development, Kolkata. Retrieved from http://www.drcsc.org

them with suggested streamlined models, the research proves that removing non-value-added (NVA) activities can lower dwell time by as much as 75%. Based on international studies (e.g., Arvis et al., 2010; Hummels & Schaur, 2012; Djankov et al., 2006), the article highlights that minimizing uncertainty and dwell times in ports has the potential to significantly reduce trade costs and enhance competitiveness.[54]

Dr. B. Swaminathan (2018) analyzes the effect of Public-Private Partnership (PPP) projects on cargo handling at Indian major and non-major ports. The research concludes that since the 1996 PPP reforms, India's port capacity and cargo handling have grown considerably, with major ports serving more than 648 million tonnes in 2016–17. The article identifies how policy reforms like the planned Indian Ports Authorities Act and changes to the Major Ports Act have promoted modernization and private investment. Deendayal, JNPT, and Paradip ports have pioneered bulk and container cargo handling, and inland container depots and direct port delivery systems streamlined logistics further. Based on global standards and past experiences, the paper contends that PPP is critical to long-term infrastructure growth, increased efficiency, and international competitiveness. It promotes disciplined PPP contracts, legal certainty, and open governance to provide long-term gains in India's shipping industry.[55]

Lokanathan (2014) evaluates the economic efficiency of Indian major ports using metrics such as cargo handled, revenue, and productivity. The research pinpoints inefficiencies based on aging infrastructure, low mechanization, and poor private sector participation. Using tools from Tongzon (2002) and Notteboom & Rodrigue (2005), the paper evaluates the competitiveness of the ports from a global perspective. It concludes that even with progress under programs such as the Maritime Agenda 2010–2020, Indian ports fall short of international standards because of regulatory fragmentation and operational delays. Lokanathan employs Planning Commission data and UNCTAD port statistics to contrast productivity trends and suggest policy changes towards landlord port models, digitization, and intermodal connectivity. The research concludes that institutional changes and private sector involvement are crucial in unlocking port efficiency and enabling India's growth in trade. The paper adds to infrastructure economics literature by connecting port performance with wider macroeconomic and policy aspects.[56]

Padhi (2016) traces the evolution of Paradip Port and its increasing economic significance for Odisha and eastern India. Commissioned in 1966, the port has since developed into a prominent seaport serving coal, iron ore, and container shipments. The author places this evolving development within national policies such as the Sagarmala Programme (Ministry of Shipping,

[54] Koley, S., Datta, B., & Mukherjee, S. (2016). Reducing dwell time related to clearing and forwarding of export and import goods at Kolkata sea and air ports. Foreign Trade Review, 51(4), 298–327. https://doi.org/10.1177/0015732516650808
[55] Swaminathan, B. (2018). An assessment of Indian port throughput on the implementation of public-private partnership (PPP) and the essentiality for its continuance. Research Review International Journal of Multidisciplinary, 3(8), 236–240. Retrieved from http://www.rrjournals.com
[56] Lokanathan, P. S. (2014). Performance of major ports in India: An economic analysis. *The Indian Economic Journal*, *62*(3), 385–397.

2015) and the Indian Maritime Agenda 2020, both of which seek to facilitate port-led growth. The paper cites important accomplishments in the form of cargo growth and industrial investments in the nearby area. Referring to development theories (Aschauer, 1989) and world port models (Notteboom & Rodrigue, 2005), Padhi stresses the potential of the port to increase regional employment and competitiveness in trade. The research concludes that the investment should go on with connectivity, mechanization, and policy coherence to make Paradip a global logistics gateway. Though largely anecdotal, the article provides sound policy analysis grounded in national and regional development models.[57]

Pattnaik et al. (2021) examine shoreline evolution in Paradip Port between 1985 and 2020 from satellite imagery and the Digital Shoreline Analysis System (DSAS). Their conclusion is that extensive erosion to the north of the port and accretion towards the south result from monsoonal variability, wave regimes, and anthropogenic activities like breakwaters. The authors attribute these transformations to changed sediment transport pathways driven by climate change-induced sea-level rise, corroborating global studies (Church & White, 2011; Luijendijk et al., 2018). The authors employ end-point rate and linear regression methods for accurate quantification and contrast their outcomes with historical shoreline baselines. Their study identifies the necessity for adaptive coastal management and engineering works to maintain navigation and infrastructure. This regional case study adds to overall climate effect studies by connecting natural and human-induced variables influencing India's fragile eastern coast.[58]

Sahoo, Panda, and Swain (2023) examine the potential of multi-modal logistics and port automation to enhance Paradip Port's operational efficiency in India. Based on stakeholder interviews, infrastructure surveys, and policy benchmarking, the research identifies cargo handling, connectivity, and digital inefficiencies. It also highlights the importance of using automation technologies such as RFID, intelligent sensors, and central control rooms to decrease turnaround time and streamline port operations. The authors take lessons from Notteboom and Rodrigue (2005) and use examples of national initiatives like the Sagarmala Project and Maritime India Vision 2030 to indicate policy consistency. They also draw upon best international practices in logistics management to push for effective multimodal systems integrating road, rail, and inland waterways. The paper concludes that Paradip Port needs a mix of infrastructure development, technology adoption, and policy support to emerge as a globally competitive logistics hub.[59]

Kumari and Sumalatha (2021) study the export and import process at Visakhapatnam Port Trust to determine inefficiencies and propose reforms. The study, based on India's Foreign Trade

[57] Padhi, A. C. (2016). Paradip Port: A new vista of development in Odisha. *Orissa Review*, *73*(10), 52–55. Retrieved from https://odisha.gov.in/
[58] Pattnaik, M. R., Samal, R. N., Saha, G., & Behera, S. C. (2021). Changes in the shoreline at Paradip Port, India in response to climate change. *Journal of Earth System Science*, *130*(8), 1–12. https://doi.org/10.1007/s12040-021-01640-9
[59] Sahoo, S., Panda, S., & Swain, S. K. (2023). Enhancing efficiency through multi-modal logistics and port automation: A case study of Paradip Port. *Journal of Maritime and Transportation Studies*, 1(1), 25–34.

Policy (2015–2020) and the Customs Act (1962), maps major phases in cargo movement—from documentation and customs clearance to shipping and delivery. Based on surveys and observations, the authors conclude that manual operations, inter-agency delays, and coordination problems impede operational efficiency. Their results support those of Arvis et al. (2010) and Djankov et al. (2006), who attribute trade logistics delay to decreased global competitiveness. The article suggests automating customs and port documentation through Port Community Systems (PCS), improving communication between stakeholders, and undertaking regular staff training. These interventions seek to minimize dwell time and enhance cargo throughput. In total, the research offers implementable suggestions on simplifying EXIM logistics towards the larger trade facilitation and port infrastructure upgrade agenda in Indian ports.[60]

Satyanarayana and Babu (2014) report a case of effective management of littoral drift at Visakhapatnam Port, ensuring navigability and minimizing siltation. Wave-induced sediment transport has traditionally caused severe sand deposits at the entrance to the port, hindering ship movement. The authors narrate an original solution through the creation of a sand trap with accompanying systematic dredging and bypassing of sand. Based on coastal engineering theory (Dean & Dalrymple, 2002) and sediment transport models (Komar, 1998), the research confirms the long-term efficacy of this technique. The information gathered from hydrographic surveys and sedimentation analysis indicated lower maintenance costs and improved port accessibility. The article compares this soft-engineering method with traditional hard-structure interventions, highlighting its flexibility to monsoonal fluctuations and environmental sustainability. As an other-wise-adoptable model for other Indian ports, the research contributes to applied literature on coastal sediment management and port operations resilience.[61]

Nagaraju, Sundar, and Ramu (2014) evaluate shoreline change along the Visakhapatnam coast through multi-temporal satellite imagery from 1988 to 2010. The research applies GIS and remote sensing techniques, specifically the Digital Shoreline Analysis System (DSAS), to measure shoreline movement. Results indicate pronounced erosion to the north of Visakhapatnam Port and accretion in southern parts, caused by both natural coastal dynamics and port-induced structures such as breakwaters. Based on coastal monitoring research (Thieler & Danforth, 1994; Kumar et al., 2010), the authors recognize seasonal wave action, monsoonal variation, and sediment transport as major forcing mechanisms of change. Analysis from the authors also shows that human-induced changes have had a strong impact on the sediment budget and coastal morphology. The research illustrates the utility of satellite data in long-term

[60] Kumari, K. S., & Sumalatha, S. (2021). A study on export and import procedures at Visakhapatnam Port Trust. *International Journal of Research in Commerce, IT & Management, 11*(8), 7–13. Retrieved from https://ijrcm.org.in/
[61] Satyanarayana, N., & Babu, R. R. (2014). Littoral drift management: A success story of Visakhapatnam Port. *Indian Ports Association Technical Journal*, 45(3), 15–22.

shoreline monitoring and justifies the application of integrated geospatial methods in coastal zone management and infrastructure planning, especially in erosion-prone urban areas.[62]

Babu and Sundaravadivelu (2005) report the design and construction of breakwaters at Ennore Port, Tamil Nadu, aimed at sheltering the harbor from high wave energy on India's eastern coast. The article reports the engineering design, sediment transport studies, and construction stages with the utilization of core material, filter layers, and concrete armor units. Wave studies, as per INCOIS data and modeled with Dean & Dalrymple (2002) techniques, were crucial in deriving seasonal variability and structural resilience. Site-specific issues like seabed softness and monsoonal effects are dealt with by the authors by accepting solutions like staged construction and toe protection. The authors draw a comparison with international practices as suggested by PIANC (1992) and USACE (2002). The case study is used as a paradigm for port infrastructure schemes in comparable geotechnical and hydrodynamic settings, stressing adaptive engineering and strict site-specific design to resist long-term coastal forces.[63]

Sundar, Vethamony, and Sharma (2011) study littoral sediment transport and shoreface changes on the Ennore coast based on a combination of field observations, satellite imagery, and numerical modeling. The study simulates pre- and post-monsoon wave-induced sediment movement using the MIKE 21 model (DHI, 2007). The study indicates that monsoonal wave dynamics drastically change the longshore sediment transport rates, which are responsible for erosion north of the breakwaters and accretion south of the port. The results concur with previous Indian coastal research (Kumar et al., 2010; Chandramohan et al., 1994) and world coastal morphology literature (Komar, 1998; Dean & Dalrymple, 2002). The authors conclude that man-made coastal defenses have interfered with natural sediment transport, and there is a need for improved shoreline monitoring and management. The authors suggest incorporating numerical models in coastal planning to forecast morphological behavior and enable sustainable development of India's susceptible coastlines.[64]

Kumar and Nithilan (2017) compare Chennai Port and JNPA, identifying differences in technology and infrastructure. JNPA excels in land area, fire safety systems, and container tracking, while Chennai Port excels in berths but falls behind in modernization. The research recommends Chennai Port implement JNPA's best practices, such as terminal expansion and high-tech technologies, to enhance competitiveness. It emphasizes the contribution of ports to India's economic growth, citing policies such as Sagarmala. The results emphasize constant

[62] Nagaraju, R., Sundar, G., & Ramu, B. (2014). Detection of shoreline changes along the Visakhapatnam coast, Andhra Pradesh from multi-temporal satellite images. *International Journal of Remote Sensing and GIS, 3*(1), 1–8. Retrieved from https://ijrsg.com/

[63] Babu, R. R., & Sundaravadivelu, M. (2005). Construction of breakwaters at Ennore Port. *Indian Ports Association Technical Journal, 47*(2), 23–32.

[64] Sundar, S., Vethamony, A., & Sharma, P. R. (2011). Littoral sediment transport and shoreline changes along Ennore on the southeast coast of India: Field observations and numerical modeling. *Journal of Coastal Research, SI(64)*, 1009–1013.

infrastructure and technological improvements to accommodate international trade needs, calling for a cluster model to enhance import-export efficiency.[65]

Swaminathan and Aravind (2024) examine Chennai Port's takeover of Kamarajar Port to enhance competitiveness and sustainability. KPL landlord model and coal-handling skills are a fit with ChPA container operations, while common infrastructure minimizes congestion. The report mentions financial pressures from ChPA pension obligations and acquisition debt but identifies synergies in cargo diversification and environmental initiatives (e.g., solar power). A suggested Terminal Decision Support Tool (TDST) combines environmental and operation metrics, following ESPO guidelines. The integration is intended to deter competition from private ports such as Krishnapatnam, drawing on rail/road connectivity for expansion.[66]

Sundar et al. (2021) evaluate shoreline change north of Chennai Port, where breakwaters interfered with sediment transport, resulting in extreme erosion. Employing DSAS and satellite imagery (2008–2020), the research identifies that transitional groynes constructed between 2004–2014 caused net accretion (up to 6.66 m/year), reversing earlier erosion (−21 m/year). Segment III exhibited maximum accretion, while Segment I stabilized vital highway corridors. The success of the groynes is due to locally designed coastals based on indigenous wave-current dynamics. The research highlights the contribution of geospatial tools in coastal management and necessitates ongoing monitoring to maintain gains.[67]

Nithya et al. (2023) examine the effect of port operations on water quality in two large harbors—Emore Fish Landing Centre and Rayapuram Fishing Harbour—on the coast of Chennai. The research compares physicochemical parameters (temperature, pH, salinity, dissolved oxygen) and nutrient levels (nitrate, nitrite, phosphate, silicate, ammonia) for a period of one year (2018–2019). Results indicate seasonal variations, with increased nutrient concentrations (e.g., nitrate: 0.172 mg/L; phosphate: 0.197 mg/L) during the monsoon season due to freshwater input and anthropogenic releases, whereas summer indicated increased salinity (33.5 psu) and pH (8.12) due to seawater intrusion. Rayapuram Harbour had greater pollution compared to Emore, due to intense fishing activities and urban runoff. The research emphasizes the necessity of ongoing surveillance to prevent ecological harm, supporting the findings of Shirodkar et al. (2010) on pollution caused by ports in India.[68]

Strengths of Chennai Port according to Purandare and Kasande (2016) are its deep draft (16m), capacity for handling (50M+ tonnes per annum), and connectivity to large hinterland. Its

[65] Kumar, V. N., & Nithilan, D. (2017). A case study about the comparison between the Chennai Port and the Jawaharlal Nehru Port. *International Journal of Interdisciplinary Research in Arts and Humanities*, *2*(1), 149–152.
[66] Swaminathan, B., & Aravind, T. S. (2024). Acquisition and conversion of Kamarajar Port into a green port by Chennai Port Authorities: A case study on sustainable operations. *Environmental Science Archives*, *3*(1), 142–151. https://doi.org/10.5281/zenodo.10949825
[67] Sundar, V., Sannasiraj, S. A., Babu, S. R., & Rajakan, G. M. M. (2021). Shoreline changes due to construction of groyne field in north of Chennai Port, India. *Environmental Monitoring and Assessment*, *193*(830), 1–15. https://doi.org/10.1007/s10661-021-09590-1
[68] Nithya, P., Dhanalakshmi, B., & Santhanam, P. (2023). Impact of water quality changes on harbour environment (Kasimedu and Emore) due to port activities of Chennai District, India. *Journal of Water Chemistry and Technology*, *45*(2), 140–146. https://doi.org/10.3103/S1063455X2302008X

weaknesses are urban congestion, aging human capital, and elevated costs as compared with international counterparts such as Dubai. Opportunities are associated with India's trade growth, particularly in containers and autos, while risks involve competition from private ports (e.g., Krishnapatnam) and environmental policies. The research focuses on modernization (e.g., Mega Container Terminal for 5M TEUs) and enhanced hinterland connectivity (e.g., Maduravoyal Expressway) as key to competitiveness. It supports De and Ghosh's (2003) research on Indian port efficiency, highlighting the necessity of public-private partnerships in dealing with inefficiencies. The study highlights Chennai Port's potential as a regional hub but cautions against stagnation in the absence of reforms.[69]

Chandrasekar (2013) examines OD interventions in Tuticorin Port Trust, recognizing the most important communication and hierarchy challenges among mid-level employees. Questioning supervisors and executives, the research concludes that experienced employees (35–40 years) want greater autonomy and training to meet targets. The study reflects action research models (Lewin, 1947), suggesting systematic activities to coordinate individual behavior with organizational goals. Suggestions include liberative leadership and skill-development programs, in line with current OD literature (Cummings & Worley, 2009). The research focus on worker-oriented interventions presents a model for Indian ports faced with bureaucratic inaction. Nevertheless, it refers to constraints on scalability owing to contextual issues such as rigid structures. This study supports Purandare and Kasande's (2016) SWOT analysis of Chennai Port, together championing HR-driven reforms in India's maritime sector.[70]

Shantha Sheela (2018) compares cargo traffic at Chennai and Tuticorin ports (2005–2015), highlighting Chennai's supremacy with 3.6L tonnes mean annual imports and 16.38% export growth, driven by its deep-draft advantage and connectivity. Tuticorin's lower cargo volume (12.3K tonnes) but stable performance (10.04% import variability) reflects niche efficiency. The research attributes the success of Chennai to India's trade liberalization (Panagariya, 2008) and infrastructure, and Tuticorin's reliability to labor-intensive export paradigms4 (Ghemawat & Patibandla, 1999). Weaknesses are congestion for Chennai and scale constraints for Tuticorin. Solutions are capacity expansion and technology implementation to maintain growth, in accordance with worldwide port studies (Haralambides, 2002). The study offers empirical evidence for policymakers to maintain port modernization, ensuring scale and stability (Shantha Sheela, 2018).[71]

Santhi (2020) offers a comprehensive analysis of the Tuticorin District, highlighting its varied attractions that include historical, religious, and economic dimensions. The historical heritage

[69] Purandare, A., & Kasande, S. P. (2016). SWOT analysis of Chennai Port (An ISO 14001:2004 certified port). *Pacific Business Review International*, *8*(9), 122–129.
[70] Chandrasekar, J. (2013). Organizational development intervention for making innovation and change: A study of Tuticorin Port Trust, Tamilnadu. *Review of HRM*, *2*, 256.
[71] Shantha Sheela, S. (2018). Trade performance with special reference to cargo traffic of Tuticorin and Chennai ports. *Hindco Research Journal*, *1*(1), 103–113.

of the region is highlighted by major archaeological sites like the ancient port of Korkai and the urn burials at Adichanallur, which reflect the region's rich history (Rea, 1904). On the religous tourism side, the district boasts of illustrious locations like the Thiruchendur Murugan Temple and Navathirupathi Vishnu shrines and attracts a huge number of pilgrims, with the Manapad coastal line providing potential locations for eco-tourism. The freedom movement role played by the district finds expression in memories like the Panchalankurichi Fort and the memorial of Kattabomman at Kayathar, highlighting its role as a nationalist contributing district. Economically, the Tuticorin Port is important in trade, even with draft constraints, and has been ISO 9002 certified, increasing its operational credibility (Santhi, 2020). The research demands better infrastructure to increase tourism and port efficiency, which is in line with current debates regarding heritage conservation (Majeed & Kasinathan, 1992) and the importance of maritime trade.[72]

Mercy and Rajalakshmi (2017) analyze Tuticorin Port's vessel and container management, highlighting its 10% annual growth and ISO 9002 certification. In spite of effective container handling, dependence on coal imports and outside factors such as policy changes restrict diversification. Performance statistics (2010–2015) indicate stability, with ANOVA/MANOVA validating cargo-type interdependencies. The Sethusamudram Project promises shorter shipping time but is bogged down by environmental issues. Logistics are boosted by modernization, but uncertainty at the international level continues. The research highlights the port's adaptability but seeks strategic diversification to avoid risks.[73]

Meiaraj and Jeyapriya (2019) studied marine water quality in the coastal region of Tuticorin Harbour with respect to industrial and urban pollution. Physico-chemical parameters (e.g., temperature, pH, sodium, chloride, oil, and grease) were investigated at three stations in the vicinity of fishing harbors, thermal power stations, and port activities. Results showed that even with pollution due to untreated sewage (18 MLD/day) and industrial effluents (11 MLD/day), all the parameters were within allowable limits according to US EPA standards. Unbalanced concentrations of sodium and chloride at Station 3 close to the new harbor pointed towards localized contamination risks. The authors stressed the importance of enhanced wastewater management to maintain marine diversity, considering Tuticorin's rapid industrialization and shipping operations.[74]

Raveendran and Sacatees (2024) examine the exports of Indian marine products compared to national data with Tuticorin's 2013–2023 contributions. CAGR and YoY growth ratios based on secondary data from NFDB, CAA, and MPEDA compare Tuticorin's export volumes

[72] Santhi, S. (2020). The important places of Tuticorin District—A study. *IDOSR Journal of Applied Sciences*, *5*(1), 22–27.
[73] Mercy, A. A., & Rajalakshmi, V. (2017). Analysis of vessel and container management. *International Journal of Management and Development Studies*, *6*(5), 23–26.
[74] Meiaraj, C., & Jeyapriya, S. P. (2019). Marine water quality studies at Tuticorin harbour coastal area. *Indian Journal of Geo-Marine Sciences, 48*(6), 943–946.

increasing notably, especially that of frozen shrimp, which is 711,099 metric tons in 2022–23. In spite of international shocks such as COVID-19, India's seafood exports hit an all-time high of $8.09 billion in 2022–23, with Tuticorin's strategic port and processing units being a key driver. Tuticorin, however, falls behind in frozen shrimp CAGR (3.87% compared to national 10.01%), due to local issues such as disease outbreaks and infrastructure deficiencies. The research promotes policy interventions improved cold chains, market diversification, and sustainable aquaculture to better align Tuticorin's growth with the national standards.[75]

2.2 LITERATURE GAP

The existing literature provides a comprehensive understanding of port performance, financial management, operational efficiency, and policy frameworks related to major ports on the East Coast of India. However, several critical gaps.

Limited Focus on Financial Strength as a Holistic Concept. Most studies (e.g., Bose, 1997; Mandal et al., 2016) analyze operational efficiency or cargo handling but lack a consolidated financial assessment incorporating profitability, liquidity, leverage, and investment efficiency. Financial sustainability is often discussed in isolation (e.g., Rawal & Sharma, 2019 on PPP financing) rather than as an integrated metric for port competitiveness.

Inadequate Comparative Financial Analysis Across East Coast Ports. While studies like Varghese et al. (2012) and Nayak et al. (2024) benchmark operational performance, few compare financial health across major ports (e.g., Chennai, Visakhapatnam, Paradip, Kolkata/Haldia, Tuticorin). The impact of varying governance models (landlord vs. service ports) on financial outcomes remains underexplored.

Neglect of Macroeconomic and Policy-Driven Financial Risks. Although risks like climate change (Ghosh, 2009) and operational inefficiencies (Sinha & Bagodi, 2018) are studied, their financial implications (e.g., dredging costs, insurance premiums, revenue loss due to disruptions) are rarely quantified. The role of recent policies (Sagarmala, Maritime India Vision 2030) in shaping port financial resilience is not rigorously evaluated.

Methodological Gaps in Financial Performance Measurement. Existing studies rely on DEA (Varghese et al., 2012) or MPI (Nanyam & Jha, 2023) for efficiency but omit financial ratios, trend analysis, or predictive modeling (e.g., cash flow forecasting, solvency risk). Subjective risk assessments (Sajith et al., 2024) lack empirical linkages to financial stability.

[75] Raveendran, A., & Sacratees, J. (2024). *Comparative dynamics in marine product exports: National trends versus Tuticorin's contribution over a decade* [Preprint]. SSRN. https://doi.org/10.2139/ssrn.4866130

Understudied Port-Specific Financial Challenges. Kolkata/Haldia's high dredging costs (Bose, 1997) and Chennai's urban congestion (Purandare & Kasande, 2016) are noted, but no study systematically compares these constraints across ports or evaluates mitigation strategies.

2.3 LITERATURE ANALYSIS

The reviewed literature reveals key themes and trends relevant to the financial strength of East Coast ports:

Operational Efficiency vs. Financial Performance. Studies like Mandal et al. (2016) and Varghese et al. (2012) highlight operational metrics (turnaround time, berth utilization) but rarely correlate them with financial outcomes (e.g., revenue per ton, return on assets).

Implication: Financial strength requires balancing efficiency (e.g., cargo throughput) with cost management (e.g., maintenance, labor).

Governance and Policy Impact. Weak regulatory autonomy (Joshi & Singh, 2017) and PPP bottlenecks (Ranganathan, 2008) hinder revenue generation and private investment.

Implication: Ports with stronger governance (e.g., JNPT) outperform others financially, but East Coast ports lag due to fragmented policies.

Regional Disparities in Financial Resilience. Paradip and Visakhapatnam show growth via industrialization (Acharya & Mishra, 2013), while Kolkata struggles with siltation costs (Bose, 1997).

Implication: Location advantages (hinterland connectivity, cargo mix) directly influence financial stability.

Emerging Risks and Financial Adaptability. Climate change (Pattnaik et al., 2021) and cybersecurity (Sajith et al., 2024) pose unquantified financial risks.

Implication: Ports must integrate risk mitigation (e.g., disaster-proof infrastructure) into financial planning.

Technology and Modernization Gaps. Automation (Sahoo et al., 2023) and digital tools (Kumari & Sumalatha, 2021) are underutilized, affecting cost efficiency.

Implication: Investment in technology (e.g., RFID, AI) could reduce operational costs and improve financial ratios.

CHAPTER 3

RESEARCH METHODOLOGY

Overview

3.1 INTRODUCTION

3.2 RESEARCH DESIGN

- 3.2.1 Title of the Study
- 3.2.2 Objectives of the Study
- 3.2.3 Nature and Scope of the Study
- 3.2.4 Variables of the Study
- 3.2.5 Formulation of Hypothesis
- 3.2.6 Selection of the Sampling Design
- 3.2.7 Period of the Study
- 3.2.8 Data Collection and Data Sources
- 3.2.9 Data Analysis
- 3.2.10 Statistical Tools and Techniques

3.3 OUTLINE OF CHAPTER PLAN

3.4 SIGNIFICANCE OF THE STUDY

3.5 LIMITATIONS OF THE STUDY

3.6 CONCLUSION

3.1 INTRODUCTION

Ports are vital to the economic development of any nation, serving as critical nodes for international trade, logistics, and transportation. On India's East Coast, major ports play a key role in supporting the country's export-import activities, industrial supply chains, and regional development. Recognizing their strategic and economic importance, significant investments and reforms have been introduced over the years to improve the operational and financial performance of these ports. In recent decades, there has been a notable transformation in the management and functioning of major ports, driven by modernization efforts, public-private partnerships, and increased global competition. This has resulted in a shift from traditional administrative models to more commercially driven, performance-oriented approaches in port operations. Despite these advancements, several challenges remain. Issues such as underutilization of capacity, high operational costs, inconsistent revenue growth, and financial inefficiencies continue to hinder the sustainable development of ports. Evaluating the financial strength of these ports is crucial to understanding their competitiveness, identifying weaknesses, and shaping future policy and investment decisions. In this context, the present study titled **"A Comparative Analysis of Financial Strength of Major Ports in East Coast"** seeks to analyze and compare the financial performance of select major ports located along the East Coast of India. The research aims to assess various financial indicators such as profitability, liquidity, efficiency, and capital structure to provide an objective view of their financial health and operational sustainability.

3.2 RESEARCH DESIGN

The researcher has adopted an exploratory research design to systematically analyse and compare the financial strength of major ports located along the East Coast of India. The components of the research design are as follows:

3.2.1 Title of the Study

The study is entitled as:
"A Comparative Analysis of Financial Strength of Major Ports in East Coast"

3.2.2 Objectives of the Study

1. To study the scope and operational framework of major ports on the East Coast of India.
2. To evaluate and compare the financial performance of selected major ports.
3. To identify and analyze the factors influencing the financial strength of these ports.
4. To examine key financial indicators such as profitability, liquidity, and operational efficiency of the ports.

3.2.3 Nature and Scope of the Study

In the contemporary economy, maritime infrastructure is a key driver of economic growth and competitiveness in trade. As strategic logistics and supply chain nodes, ports have changed substantially over the last few decades. This research particularly addresses the assessment of the financial stability of the key ports of India's East Coast, which are strategically significant because of their location and regional trade corridors as well as industrial development contributions. Though India has many ports along its coast, the study consciously confines itself to six major East Coast ports - Chennai, Visakhapatnam, Paradip, Kamarajar (Ennore), V.O. Chidambaranar (Tuticorin), and Kolkata - to allow a focused comparative financial analysis. Exclusion of minor and private ports is done with a conscious strategy in mind because their different ownership models, financial reporting norms, and operational mechanisms would bring in variables outside the scope of the study. The period of analysis is FY2019 to FY2024, five years chosen to reflect significant financial trends, monitor the development of port health, and analyze the effect of policy reforms and infrastructural improvements. By focusing on three key areas - comparative financial performance between chosen ports, analysis of major financial benchmarks (such as profitability, liquidity and efficiency levels), and identifying relative strengths as well as potential areas for improvement - the study hopes to derive actionable recommendations to port authorities, policymakers and future investors. The results will aim to enrich academic literature alongside informing pragmatic policy frameworks for increasing financial sustainability and operational efficiency in India's vital port industry. This focused analysis of East Coast major ports' financial systems will ensure a systematic grasp of their existing fiscal position, thus facilitating evidence-based decision-making for prospective infrastructure investments and policy making in India's maritime sector.

3.2.4 Variables of the Study

To assess the financial strength of major ports on the East Coast of India, the study focuses on five key financial variables that offer a comprehensive view of their fiscal performance and stability. These variables include Current Liabilities, Investment, Total Assets, Operating Income, and Operating Expenditure. Current Liabilities reflect the short-term financial obligations of the ports, indicating their liquidity and ability to meet immediate financial commitments. Investment represents the capital allocation made by the ports to enhance infrastructure and operational capacity. Total Assets provide insight into the scale and economic footprint of each port, serving as a measure of their resource base. Operating Income evaluates the revenue generated through core port operations, while Operating Expenditure captures the costs incurred in maintaining and running those operations. Together, these variables form the basis for a comparative financial analysis of the selected ports over the period 2019 to 2024.

3.2.5 Formulation of Hypothesis

To evaluate and compare the financial performance of selected major ports on the East Coast of India, the researcher has formulated the following hypothesis and employed statistical testing for significance:

ANOVA F-Test

To further analyze the financial performance of multiple major ports, the researcher has employed an ANOVA (Analysis of Variance) F-test. This test is useful in determining whether there are statistically significant differences in financial performance across more than two groups—in this case, different ports. The ANOVA F-test helps compare multiple means simultaneously based on selected financial indicators (e.g., profitability and liquidity ratios), without increasing the risk of Type I error as would happen with multiple t-tests.

Hypotheses Formulated:

- **Null Hypothesis (H_0):**
  There is no significant difference in the financial performance of the selected major ports on the East Coast of India during the period of study.
- **Alternative Hypothesis (H_1):**
  There is a significant difference in the financial performance of the selected major ports on the East Coast of India during the period of study.

By applying the ANOVA F-test, the study aims to validate whether observed differences in financial outcomes among the ports are statistically meaningful.

3.2.6 Selection of the Sampling Design

Selected Sample: As per the available data, India has 12 major ports managed under the Ministry of Ports, Shipping and Waterways. Among these, several are located on the East Coast of India. For the purpose of this study, **6 major ports** have been selected based on their operational scale, cargo handling volume, and data availability.

Sample Size: The study includes **6 major ports** from the East Coast of India, selected through purposive sampling to represent a fair and diverse overview of port operations.

Selected Major Ports:

1. **Chennai Port**
2. **Visakhapatnam Port**
3. **Paradip Port**
4. **Kamarajar (Ennore) Port**
5. **Kolkata Port**
6. **VOC**

3.2.7 Period of the Study

To analyze trends and changes in financial performance, the study covers a **06-year period** from **1st April 2019 to 31st March 2024**. This time frame provides a comprehensive view of financial progress, operational developments, and policy impacts.

3.2.8 Data Collection and Data Sources

This study is based on **secondary data** collected from credible and publicly available sources. The main sources of data include:

- Annual Reports of the selected major ports
- Ministry of Ports, Shipping and Waterways (Government of India)
- Indian Ports Association (IPA) publications
- Major Port Authorities Act data releases
- Comptroller and Auditor General (CAG) reports (for public ports)
- Port Trust websites and official financial disclosures

3.2.9 Data Analysis

The collected data is systematically compiled, classified, and tabulated for effective analysis. Graphical representation and comparative tables are used to highlight trends and differences among ports. The analysis includes:

- **Ratio Analysis** (Profitability, Liquidity, Efficiency)
- **Comparative Analysis**
- **Statistical Tools**: ANOVA F-Test are applied to test the significance of differences in financial performance among the ports.

All findings are interpreted in line with the objectives of the study to draw meaningful conclusions and policy implications.

3.2.10 Statistical Tools and Techniques

To analyze and interpret the financial performance of selected major ports on the East Coast of India, the researcher has applied the following statistical tools and techniques:

ANOVA Test (One-Way Classification F-Test):

The **Analysis of Variance (ANOVA)** F-test is employed to examine the significance of differences in **profitability and liquidity ratios** across all selected ports.

- ANOVA is used for comparing more than two groups simultaneously.
- The test is performed at a **5% level of significance** to ensure statistical reliability.
- The **degrees of freedom (df)** used are based on: **df = (n - 1)**, where *n* is the number of ports analyzed.
- One-way classification ANOVA helps determine whether the differences in financial performance across the five selected ports are statistically significant.

The statistical findings are supported through **tabulated results and graphical presentations**, helping to draw comparative conclusions about the financial strength of each port.

3.3 OUTLINE OF CHAPTER PLAN

This study divided into eight chapters which are as follow:

Chapter 1: Introduction

Chapter 2: Literature Review

Chapter 3: Research Methodology

Chapter 4: Profitability analysis

Chapter 5: Correlation Analysis

Chapter 6: Comparative analysis

Chapter 7: Summary, Findings, Suggestions and Conclusion

3.4 SIGNIFICANCE OF THE STUDY

With rising competition and demands for greater efficiency in maritime logistics, key ports along India's East Coast are experiencing increased pressure to improve their bottom lines and operating efficiencies. Globalization and expanding volumes of trade have required strategic changes to make way for sustainable growth, financial autonomy, and better service provision. This research assesses the financial performance and strength of selected major East Coast ports for ten years, appreciating their increasing role beyond cargo facilitation to strategic trade facilitation. Knowledge of their financial health is pivotal to policymakers, investors, and port authorities to make informed choices that foster growth and competitiveness.

Through the use of important financial metrics like profitability and liquidity ratios, the research offers crucial information regarding the financial sustainability and viability of these ports. It focuses on the determinants of profitability and financial health, detects differences in performance for various ports, and investigates potential explanations for such variations. The analysis of financial metrics assists in identifying strengths and weaknesses in the financial

management of ports, providing evidence-based recommendations for enhancing efficiency, investment planning, and resource allocation.

Ultimately, this study provides a comparative financial insight that can:

- Improve accountability and transparency in port operations.
- Inform infrastructure development and modernization efforts.
- Inform academic research and government policy initiatives for port-sector reforms.

By addressing these dimensions, the study is a part of the larger objective of improving India's maritime trade infrastructure and providing long-term financial stability in the port sector.

3.5 LIMITATIONS OF THE STUDY

Although this research offers useful information on the financial performance of large ports along India's East Coast, it should be noted that there are a number of limitations that can influence the scope and interpretation of the results. To begin with, the analysis is mainly focused on financial measures and performance metrics, which, although useful, provide a narrow view of overall port efficiency and operational effectiveness. Second, the use of secondary data from published yearly reports, government websites, and official publications leaves the accuracy and consistency of conclusions dependent on the reliability of such sources. Third, the study is limited to only six big ports on the East Coast and does not cover West Coast ports, non-major ports, or private terminals, which could limit the generalizability of results to the larger Indian port industry. Fourth, although statistical methods like f-tests and ANOVA were used to confirm results, these are subject to built-in limitations in terms of their assumptions and interpretive scope. Lastly, external variables like policy shifts, world trade fluctuations, and infrastructure advancements, which can have considerable impact on port performance, were not explicitly integrated into the analysis. These constraints underscore the necessity for careful interpretation of the findings and hint at potential future research directions in order to supply a more sophisticated understanding of port financial performance.

3.6 CONCLUSION

This study explores and compares the financial performance of key ports on India’s East Coast over the past decade, focusing on profitability and liquidity. It examines how these ports manage financial health despite operational challenges, competition, and high investment demands. Using tools like F-tests, ANOVA, and regression analysis on secondary data, the study highlights differences in performance and identifies areas for improvement. It offers practical suggestions for better financial management and policy alignment, aiming to boost port competitiveness. Overall, the research provides valuable insights to help drive sustainable growth and informed decision-making in India's maritime sector.

CHAPTER 4

OPERATIONAL EFFICIENCY MATRIX (OEM)

Overview

4.1 PORT FINANCIAL HEALTH: AN OVERVIEW

4.1.1 Revenue Generation and Cost Management

4.1.2 Financial Evaluation Parameters

4.1.3 Financial Indicators for Operational Efficiency Metrics Analysis

4.2 OEM OF VOC PORT

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4.6 OEM OF PARADIP PORT AUTHORITY

4.7 OEM OF SYAMA PRASAD MOOKERJEE PORT AUTHORITY

4.8 CONCLUSION

4.1 PORT FINANCIAL HEALTH: AN OVERVIEW

The financial health of a port serves as a vital measure of its operational efficiency, sustainability, and economic contribution. Financially stable ports facilitate seamless logistics, support infrastructure development, and maintain competitive service quality. Critical financial metrics—including profitability, liquidity, and asset management—determine a port's revenue generation capacity, cost management efficiency, and long-term viability (Notteboom & Rodrigue, 2022).

4.1.1 Revenue Generation and Cost Management

Ports earn revenues through a portfolio of diversified revenue sources that cover cargo handling charges, ship service charges, lease deals like terminal concessions, and added-value logistic services. The revenues from these sources help secure port operations financially. Yet, the profitability of ports also largely depends on a number of external variables such as global demand for trade, shipping industry trends, regulatory policy changes, and the magnitude of capital investment poured into infrastructure growth. Efficient ports, according to the World Bank (2020), are those that manage their operating expenses effectively—labor, maintenance, and fuel, for instance—while also maximizing revenue collection. This balance is important not just for profitability but also for underwriting more general aims of regional and national economic development.

4.1.2 Financial Evaluation Parameters

Port financial performance is assessed through several key factors. Revenue is divided into operating income from core activities like cargo handling, and non-operating income from things like property rentals or investments. This helps show how much a port earns from its main operations versus other sources. On the cost side, fixed expenses (like infrastructure maintenance and depreciation) are separated from variable expenses (like fuel and labor). Another important measure is how efficiently a port uses its assets to generate output. Liquidity and solvency ratios indicate whether a port can meet short-term bills and handle long-term financial responsibilities. As Ducruet and Notteboom (2022) note, financially strong ports can invest in upgrades, go green, and connect with global trade networks—while weaker ports often struggle with outdated infrastructure and poor service, limiting their role in economic growth.

4.1.3 Financial Indicators for Operational Efficiency Metrics Analysis

This study evaluates the financial health of selected ports using the following indicators:

Revenue Per Vessels

$$Revenue\ Per\ Vessels = \frac{Operating\ Income}{Number\ of\ Vessels\ Handle}$$

Vessels Per Berth

$$Vessels\ Per\ Berth = \frac{Number\ of\ Vessels\ Handle}{Number\ of\ Berth}$$

Employees Productivity

$$Employees\ Productivity = \frac{Operating\ Income}{Number\ of\ Employees}$$

4.2 OPERATIONAL EFFICIENCY MATRIX OF VOC PORT

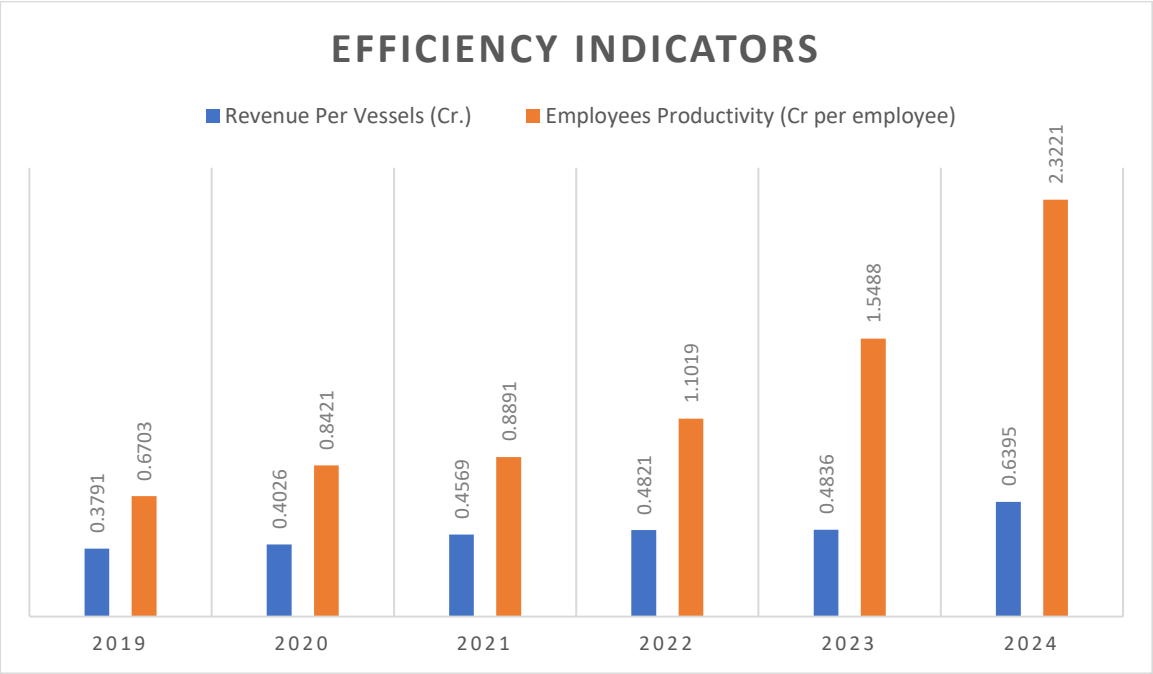
The prepared table shows profitability position of VOC Port of India for the year 2019 to 2024. Here, there are different ratios calculated for performance evaluation of VOC Port India for the six years.

Table 4.1: Operational Efficiency Matrix of VOC Port

VOC Port	2019	2020	2021	2022	2023	2024
Operating Income (Cr)	519.50	582.90	549.52	596.81	736.92	984.78
Number of Vessels Handle	1370	1447	1203	1238	1524	1540
Number of Employees	775	692	618	542	476	424
Number of Berth	15	15	15	15	16	16
Revenue Per Vessels (Cr.)	0.3791	0.4026	0.4569	0.4821	0.4836	0.6395
Vessels Per Berth	91.33	96.47	80.20	82.25	95.25	96.25
Employees Productivity	0.6703	0.8421	0.8891	1.1019	1.5488	2.3221

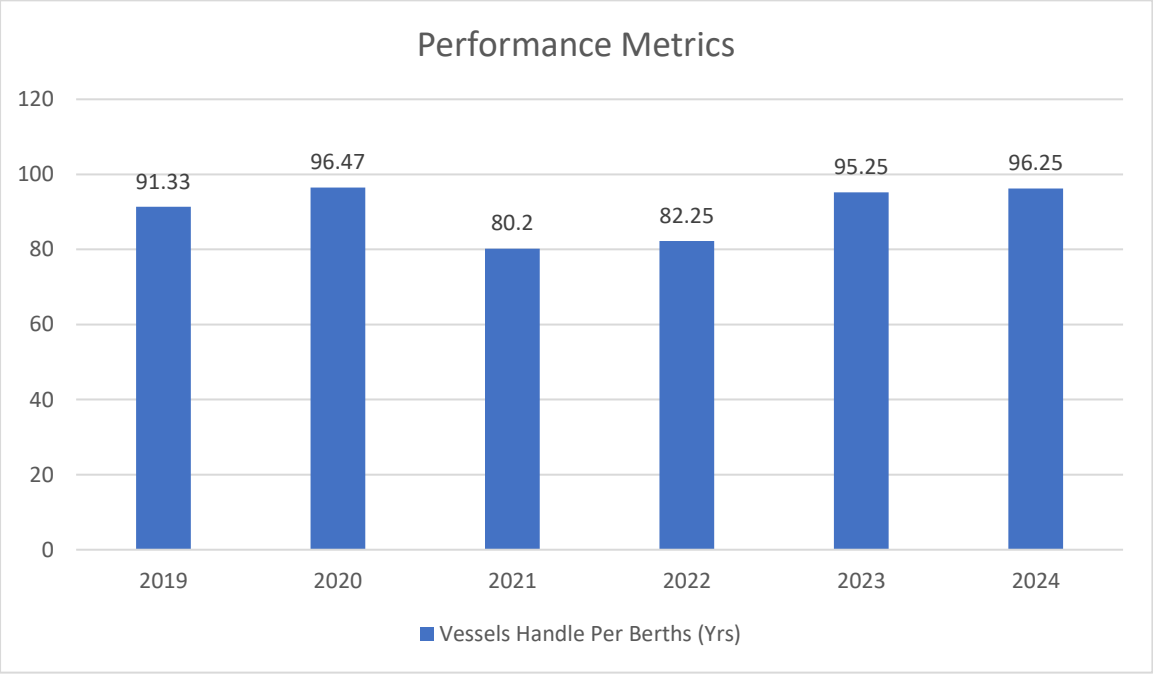
Source: V.O. Chidambaranar Port Authority. (2019-2024). 40TH & 45TH Administration Report 2019–2024.

Chart 4.1 Efficiency Indicators on VOC Port



Source: V.O. Chidambaranar Port Authority. (2019-2024). 40TH & 45TH Administration Report 2019–2024.

Chart 4.2 Vessels Performance Metrics on VOC Port



Source: V.O. Chidambaranar Port Authority. (2019-2024). 40TH & 45TH Administration Report 2019–2024.

VOC Port, one of the major ports on India's east coast, has performed remarkably well between 2019 and 2024. Its income from operations almost doubled—from ₹519.50 crore in 2019 to ₹984.78 crore in 2024—thanks to better cargo handling, smarter pricing, and more efficient operations. Although ship traffic dropped in 2021 due to the pandemic, it bounced back strongly, reaching 1,540 vessels by 2024—surpassing pre-COVID levels. The port added just one new berth (from 15 to 16), yet managed to handle more ships, showing smart use of infrastructure. What stands out is the sharp drop in workforce—from 775 employees in 2019 to 424 in 2024. But this didn't hurt performance—in fact, it improved it. Revenue per employee rose from ₹0.67 crore to ₹2.32 crore, pointing to successful automation and better management. Revenue per ship also increased, meaning the port is handling either larger ships or charging more effectively. Berth usage stayed consistent, showing efficient planning. In short, VOC Port has become more productive and profitable, even with fewer workers and minimal expansion. Its use of technology and focus on efficiency has turned it into a competitive and future-ready port.

4.3 OPERATIONAL EFFICIENCY MATRIX OF CHENNAI PORT AUTHORITY:

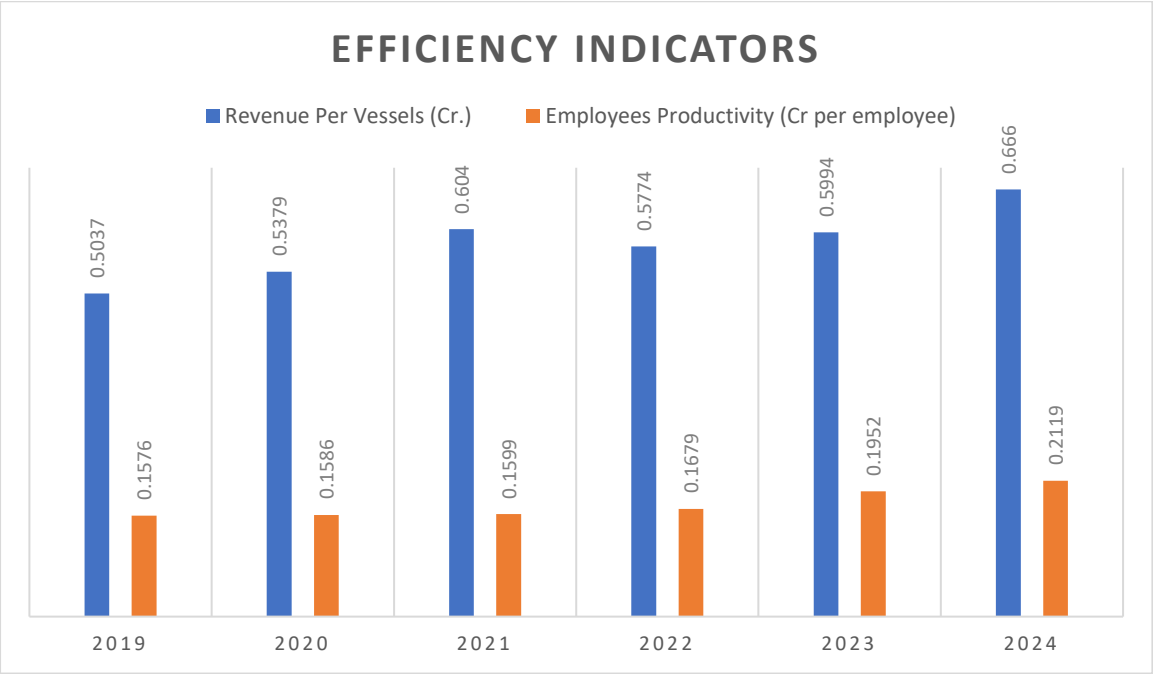
The prepared table shows profitability position of Chennai Port Authority of the India for the year 2019 to 2024. Here, there are different ratios calculated for performance evaluation of Chennai Port Authority of the India for the six years.

Table 4.2: Operational Efficiency Matrix of Chennai Port Authority

VOC Port	2019	2020	2021	2022	2023	2024
Operating Income (Cr)	809.08	787.55	794.33	833.76	968.77	1051.67
Number of Vessels Handle	1606	1464	1315	1444	1616	1579
Number of Employees	5132	4965	4965	4965	4963	4963
Number of Berth	24	26	26	26	26	26
Revenue Per Vessels (Cr.)	0.5037	0.5379	0.6040	0.5774	0.5994	0.6660
Vessels Per Berth	66.92	56.31	50.58	55.54	62.15	60.73
Employees Productivity	0.1576	0.1586	0.1599	0.1679	0.1952	0.2119

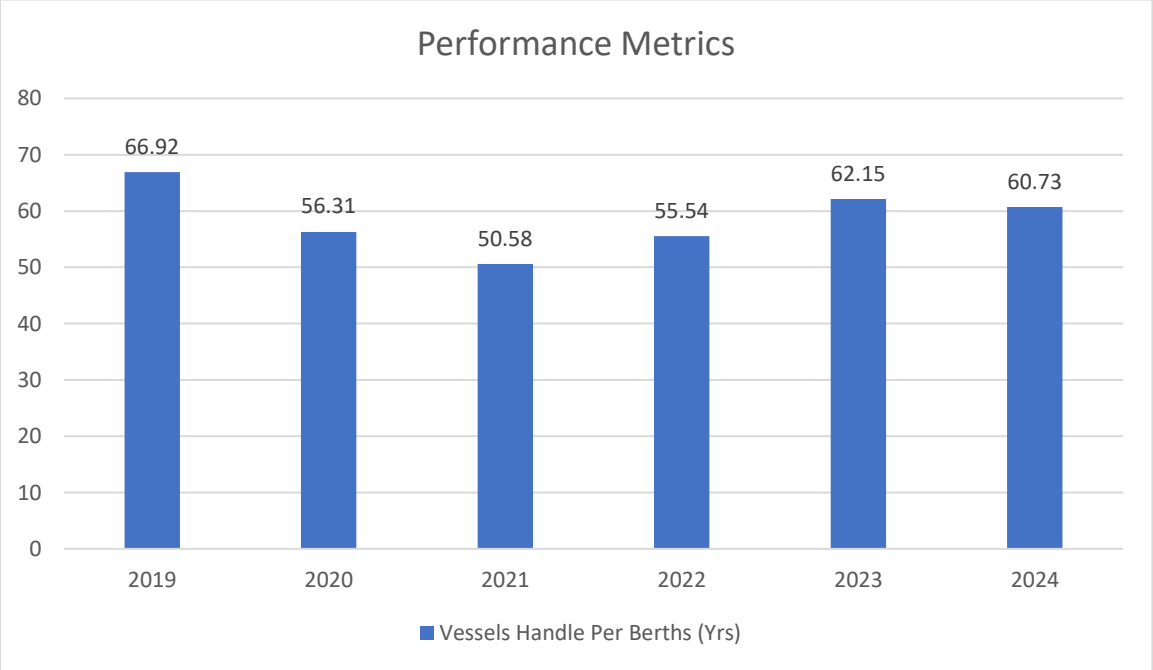
Source: Chennai Port Authority. (2019-2024). Administration Report 2019–2024.

Chart 4.3 Efficiency Indicators on Chennai Port Authority



Source: Chennai Port Authority. (2019-2024). Administration Report 2019–2024.

Chart 4.4 Vessels Performance Metrics on Chennai Port Authority



Source: Chennai Port Authority. (2019-2024). Administration Report 2019–2024.

The Chennai Port Authority, which is among the oldest and most active ports on India's east coast, has shown consistent operational resilience and financial solidity from 2019 to 2024. The period during this time displays a balanced strategy towards revenue augmentation, workforce management, and infrastructure utilization.

The port's operating income has a positive year-on-year growth trend, beginning from ₹809.08 crore in the year 2019 and growing to ₹1,051.67 crore in 2024. While it did drop slightly in 2020—due possibly to the impact of the COVID-19 pandemic—revenues have gone up year-on-year consistently since then. The trend suggests a robust bounce-back and proves the capacity of the port to improve its cargo handling and service efficiency in a competitive context.

Ship traffic reduced temporarily in 2020 and 2021, declining to 1,315 ships in 2021 from 1,606 in 2019. The port, however, bounced back, with 1,616 ships being handled in 2023. The figure slightly decreased to 1,579 in 2024, but remained higher than the majority of pandemic-era levels. In spite of these variations, revenue per ship showed a considerable increase—from ₹0.5037 crore in 2019 to ₹0.6660 crore in 2024. This increase indicates that the port either carried more costly cargo or perfected its fee structure, increasing its revenue despite carrying fewer ships in certain years.

The number of vessels per berth measure varied according to traffic volume, lowering to 50.58 in 2021 but rising above 60 by 2024. The port held 26 berths starting 2020, demonstrating a stable infrastructure configuration that accommodates steady vessel operations.

The headcount was relatively stable at about 4,965 for the six years. Yet, employee productivity—defined by employee income—increased from ₹0.1576 crore in 2019 to ₹0.2119 crore in 2024. This rise indicates enhanced efficiency of the workforce, which could be attributed to improved management practices, technology adoption, and optimization in the ports.

In short, Chennai Port Authority demonstrated resilience, strategic expansion, and improved operating efficiency over the years. With steady revenue growth, stable infrastructure, and increasing productivity, the port continues to be a prime player in India's maritime economy. Further emphasis on digitalization, capacity utilization, and cargo diversification will make it an even stronger player in the coming years.

4.4 OPERATIONAL EFFICIENCY MATRIX OF KAMARAJAR PORT LIMITED:

The prepared table shows profitability position of Kamarajar Port Limited of India for the year 2019 to 2024. Here, there are different ratios calculated for performance evaluation of Kamarajar Port Limited India for the six years.

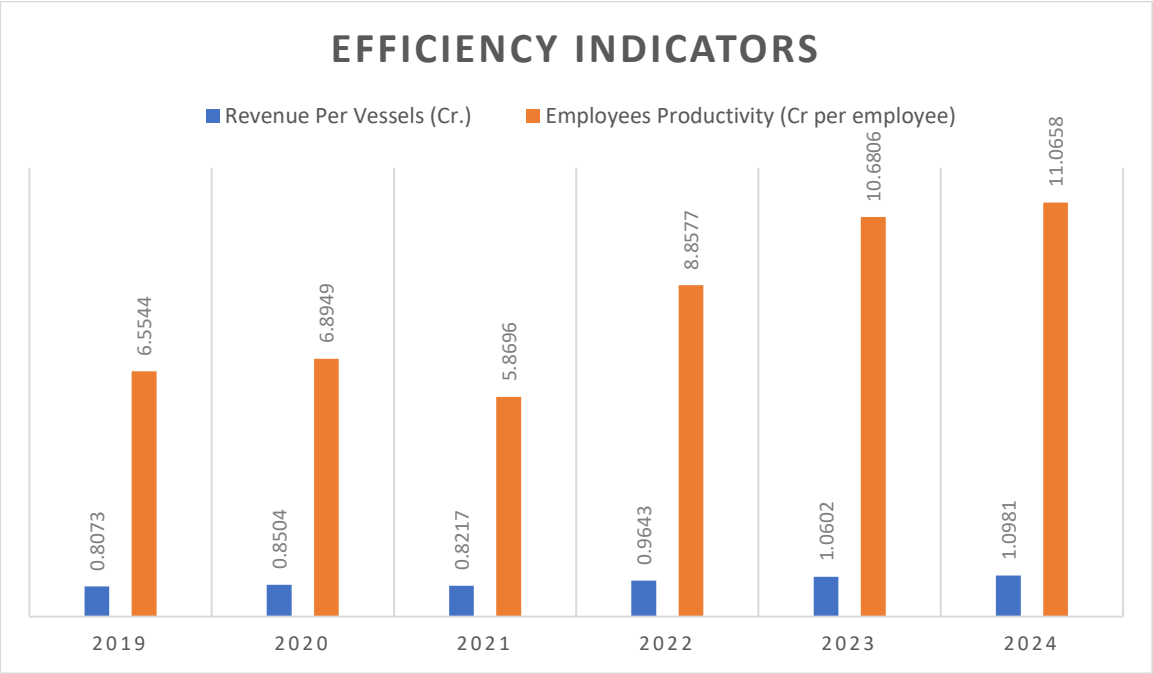
Table 4.3: Operational Efficiency Matrix of Kamarajar Port Limited

VOC Port	2019	2020	2021	2022	2023	2024
Operating Income (Cr)	707.98	703.18	581.09	832.62	982.72	1062.22
Number of Vessels Handle	877	827	707	863	927	967
Number of Employees	108	102	99	94	92	96
Number of Berth	7	7	7	7	7	7
Revenue Per Vessels (Cr.)	0.8073	0.8504	0.8217	0.9643	1.0602	1.0981
Vessels Per Berth	125.29	118.14	101.00	123.29	132.43	138.14
Employees Productivity	6.5544	6.8949	5.8696	8.8577	10.6806	11.0658

Source: Kamarajar Port Limited. (2019-2024).19th-24th Administration Report 2019–2024.

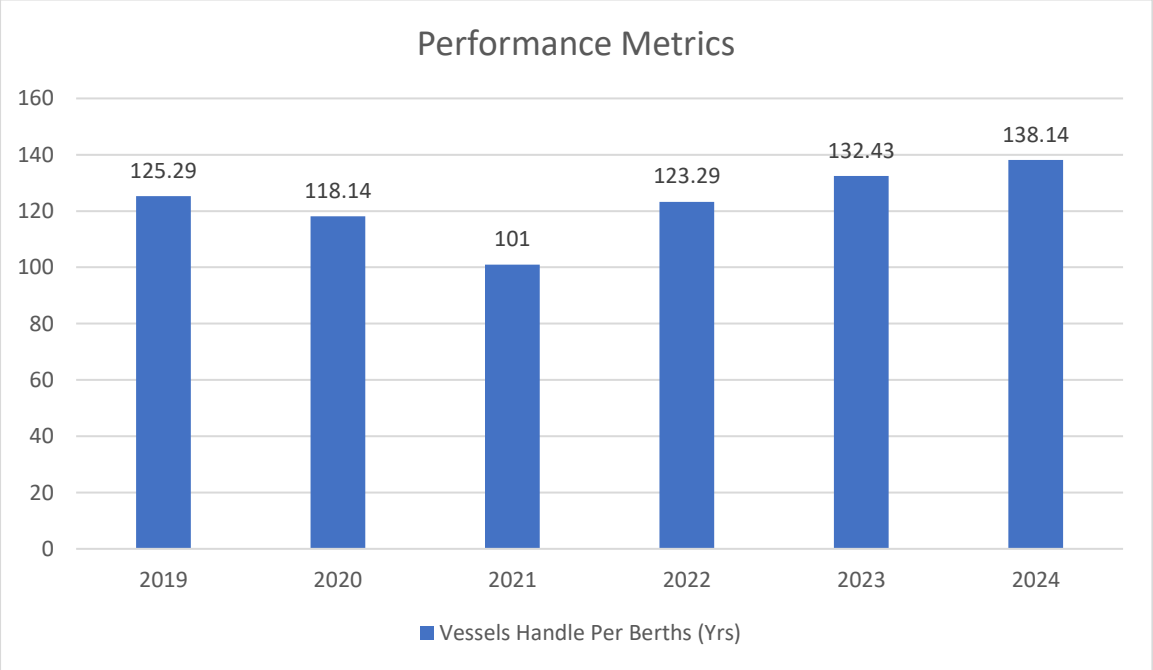
Kamarajar Port Limited, India's newest and most up-to-date port, has displayed impressive operational effectiveness and financial resilience over the six years from 2019 to 2024. The port has persistently grown in strategic performance parameters like revenue generation, vessel traffic management, and worker productivity. The operating income increased consistently from ₹707.98 crore in 2019 to ₹1,062.22 crore in 2024, representing a total rise of approximately 50%. This increase is evidence of the port's strategic prioritization of increasing cargo throughput, diversification of activities, and service quality. Further, even during 2020 and 2021—years characterized by global trade disruptions caused by COVID-19—the port was able to record comparatively stable revenues, which establishes the port's operational resilience.

Chart 4.5 Efficiency Indicators on Kamarajar Port Limited



Source: Kamarajar Port Limited. (2019-2024).19th-24th Administration Report 2019–2024.

Chart 4.6 Vessels Performance Metrics on Kamarajar Port Limited



Source: Kamarajar Port Limited. (2019-2024).19th-24th Administration Report 2019–2024.

Kamarajar Port has shown impressive performance from 2019 to 2024, especially in how efficiently it operates. Revenue per vessel rose from ₹0.8073 crore in 2019 to ₹1.0981 crore in 2024 well above many other Indian ports suggesting a focus on high-value or bulk cargo and smart pricing. Even with only seven berths, the port handled more ships over time, showing excellent use of its limited infrastructure. One of the most striking achievements is employee productivity. While the workforce dropped slightly from 108 to 96, revenue per employee soared from ₹6.55 crore to ₹11.07 crore. This shows a lean, efficient setup likely powered by automation and skilled staff. In summary, Kamarajar Port runs a tight, efficient operation growing revenue, maximizing infrastructure, and keeping manpower highly productive. It sets a strong example for how ports can support India's maritime growth with world-class efficiency.

4.5 OPERATIONAL EFFICIENCY MATRIX OF VISAKHAPATNAM PORT AUTHORITY

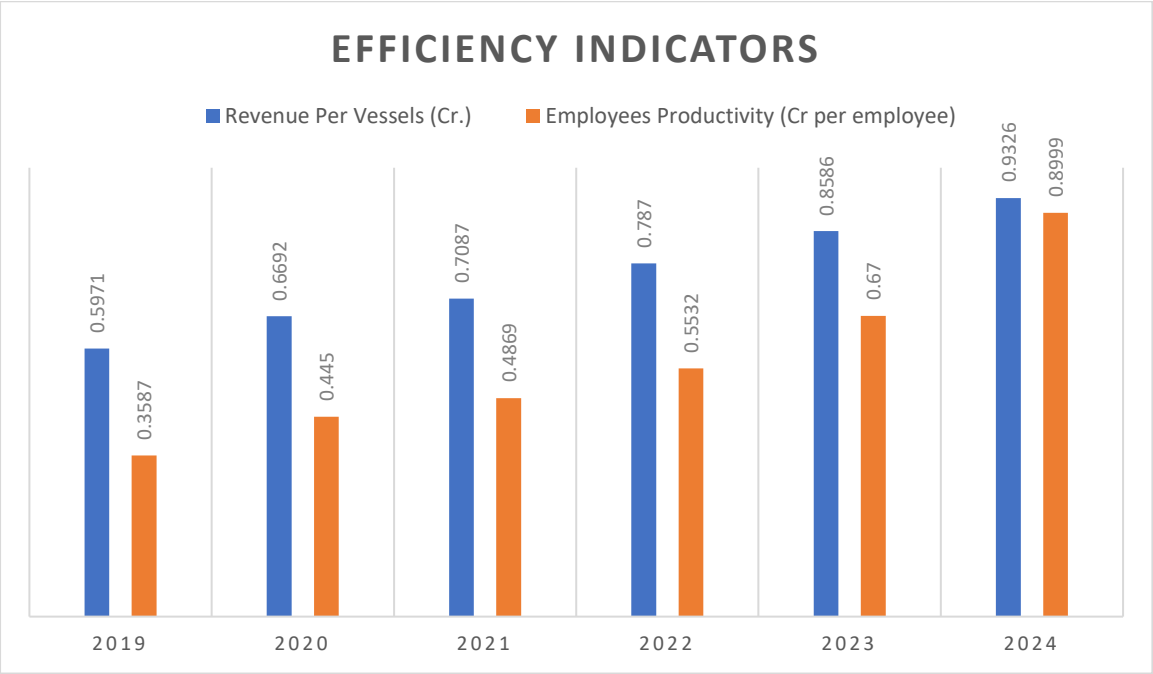
The prepared table shows profitability position of Visakhapatnam Port Authority of the India for the year 2019 to 2024. Here, there are different ratios calculated for performance evaluation of Visakhapatnam Port Authority of the India for the six years.

Table 4.4- Operational Efficiency Matrix of Visakhapatnam Port Authority

VOC Port	2019	2020	2021	2022	2023	2024
Operating Income (Cr)	1201.39	1404.18	1445.69	1525.90	1726.86	2074.75
Number of Vessels Handle	2012	2099	2040	1939	2011	2225
Number of Employees	2641	2522	2398	2217	2086	1858
Number of Berth	25	25	25	25	25	25
Revenue Per Vessels (Cr.)	0.5971	0.6692	0.7087	0.7870	0.8586	0.9326
Vessels Per Berth	80.48	83.96	81.60	77.56	80.44	89.00
Employees Productivity	0.4549	0.5568	0.6027	0.6884	0.8279	1.1165

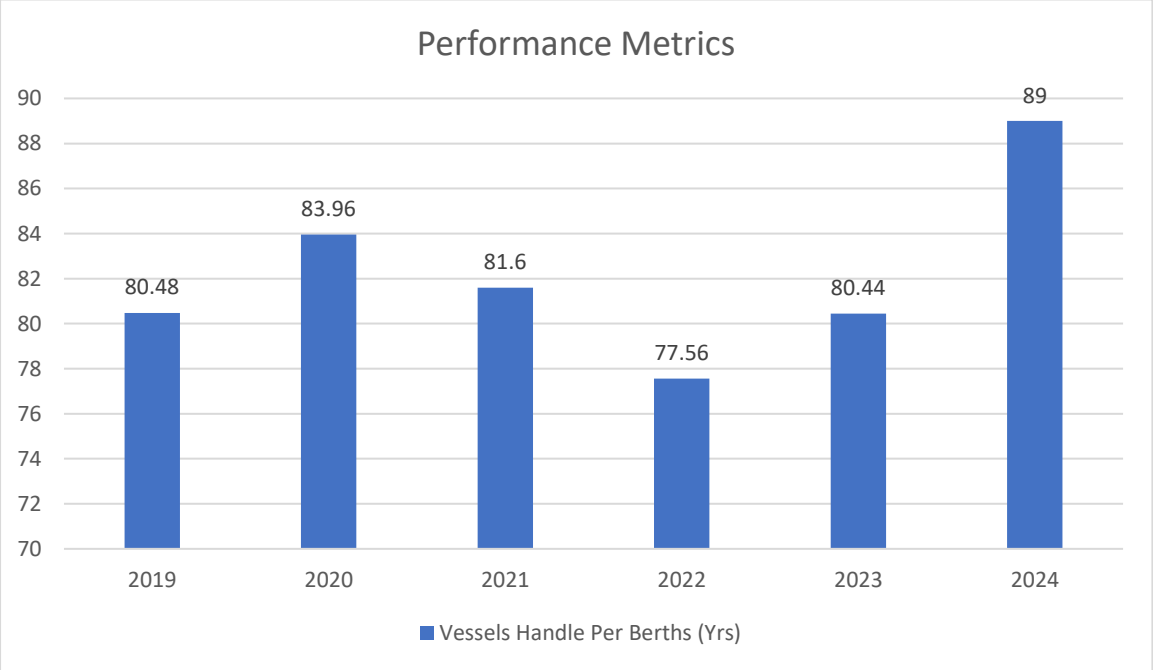
Source: Visakhapatnam Port Authority. (2019-2024). Administration Report 2019–2024.

Chart 4.7 Efficiency Indicators on Visakhapatnam Port Authority



Source: Visakhapatnam Port Authority. (2019-2024). Administration Report 2019–2024.

Chart 4.8 Vessels Performance Metrics on Visakhapatnam Port Authority



Source: Visakhapatnam Port Authority. (2019-2024). Administration Report 2019–2024.

Visakhapatnam Port Authority (VPA) showed clear signs of growth and efficiency between 2019 and 2024, positioning itself as one of the most progressive ports on India's east coast. Revenue per vessel rose steadily from ₹0.5971 crore in 2019 to ₹0.9326 crore in 2024, pointing to better cargo handling, service pricing, and operational strategies. Despite no increase in berth numbers, the port managed to handle more ships vessels per berth grew from 80.48 to 89.00 highlighting efficient scheduling and faster turnaround. The biggest leap was in employee productivity. Even as staff numbers dropped from 2,641 to 1,858, revenue per employee more than doubled from ₹0.4549 crore to ₹1.1165 crore. This reflects smart use of digital tools, automation, and better workforce management. Overall, VPA's ability to boost revenue, use infrastructure efficiently, and do more with fewer people shows strong leadership and alignment with global port standards. These consistent improvements not only strengthen its position among Indian ports but also make it a preferred hub for international maritime trade.

4.6 OPERATIONAL EFFICIENCY MATRIX OF PARADIP PORT AUTHORITY:

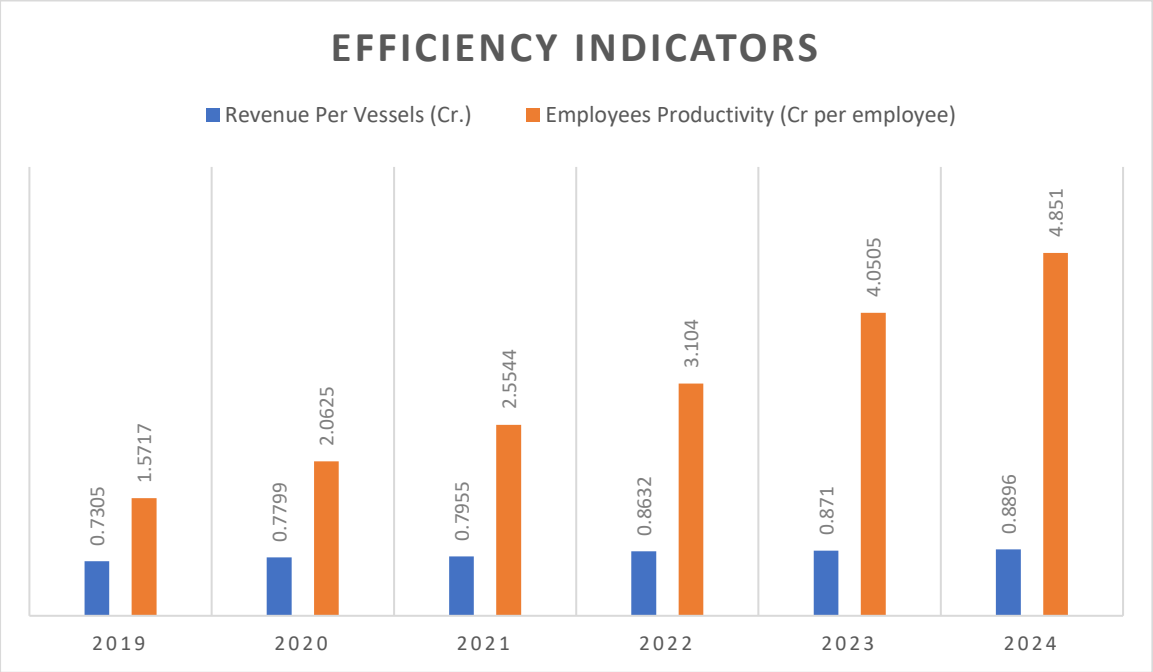
The prepared table shows profitability position of Paradip Port Authority of the India for the year 2019 to 2024. Here, there are different ratios calculated for performance evaluation of Paradip Port Authority of the India for the six years.

Table 4.5- Operational Efficiency Matrix of Paradip Port Authority

VOC Port	2019	2020	2021	2022	2023	2024
Operating Income (Cr)	1430.26	1563.26	1631.73	1732.32	2073.65	2411.86
Number of Vessels Handle	1957	2004	2051	2007	2381	2710
Number of Employees	910	758	639	558	512	497
Number of Berth	15	16	17	19	19	19
Revenue Per Vessels (Cr.)	0.7305	0.7799	0.7955	0.8632	0.8710	0.8896
Vessels Per Berth	130.47	125.25	120.65	105.63	125.32	142.63
Employees Productivity	1.5717	2.0625	2.5544	3.1040	4.0505	4.8510

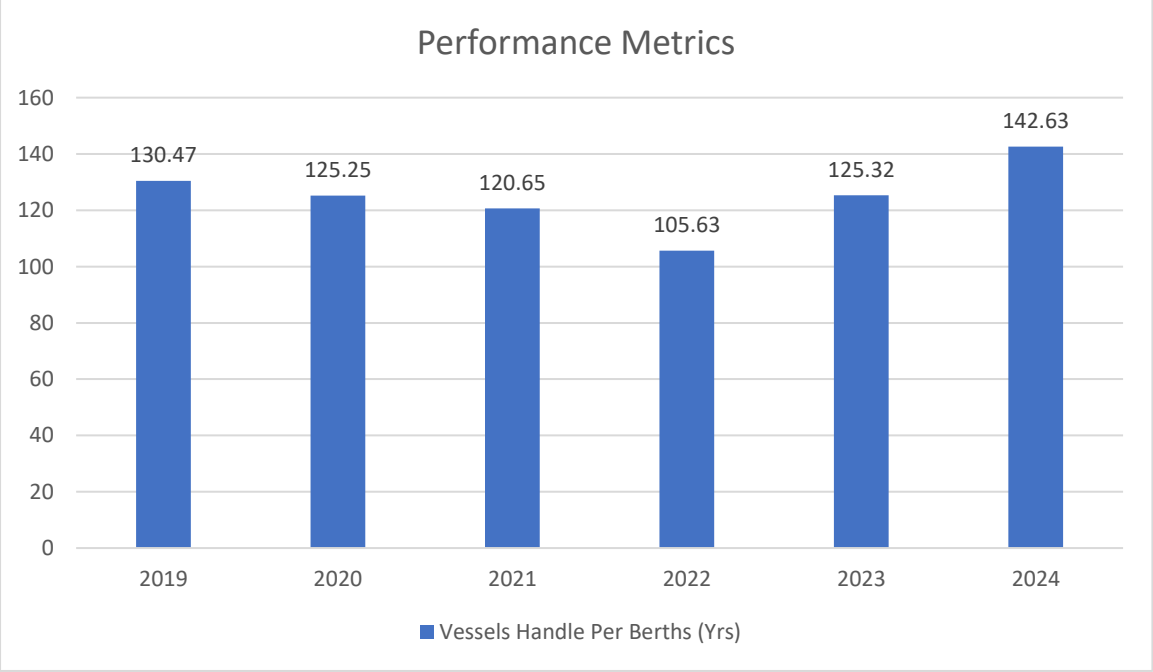
Source: Paradip Port Authority. (2019-2024). Administration Report 2019–2024.

Chart 4.9 Efficiency Indicators on Paradip Port Authority



Source: Paradip Port Authority. (2019-2024). Administration Report 2019–2024.

Chart 4.10 Vessels Performance Metrics on Paradip Port Authority



Source: Paradip Port Authority. (2019-2024). Administration Report 2019–2024.

Paradip Port Authority has shown impressive growth from 2019 to 2024, becoming more profitable and efficient. Revenue per vessel steadily rose from ₹0.73 crore to ₹0.89 crore, with a big jump after 2021, likely due to better cargo handling and tariff changes post-COVID. The port also managed to service more vessels per berth, increasing from about 130 to 143 vessels per berth, thanks to smarter scheduling and infrastructure upgrades without adding more berths. Most notably, employee productivity tripled from ₹1.57 crore to ₹4.85 crore per employee even as the workforce nearly halved. This suggests the port got a lot more efficient by using automation and better workforce management. Overall, Paradip Port's strong performance shows it's growing smarter and faster, standing out as one of India's top-performing ports.

4.7 OPERATIONAL EFFICIENCY MATRIX OF SYAMA PRASAD MOOKERJEE PORT, KOLKATA

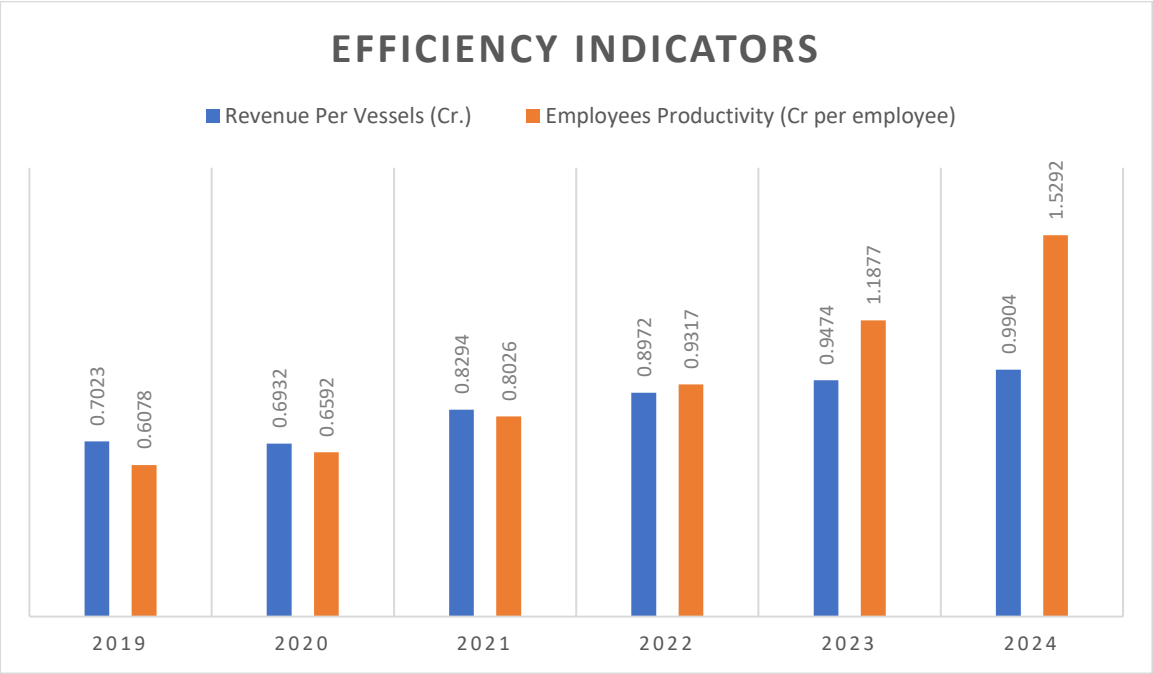
The prepared table shows profitability position of Syama Prasad Mookerjee Port, Kolkata of the India for the year 2019 to 2024. Here, there are different ratios calculated for performance evaluation of Syama Prasad Mookerjee Port, Kolkata of the India for the six years.

Table 4.6- Operational Efficiency Matrix of Syama Prasad Mookerjee Port

VOC Port	2019	2020	2021	2022	2023	2024
Operating Income (Cr)	2548.62	2443.87	2624.53	2642.37	2895.09	3227.67
Number of Vessels Handle	3628	3527	3163	2945	3056	3259
Number of Employees	4193	3708	3270	2836	2437	2110
Number of Berth	52	51	52	52	54	54
Revenue Per Vessels (Cr.)	0.7023	0.6932	0.8294	0.8972	0.9474	0.9904
Vessels Per Berth	69.77	69.16	60.83	56.63	56.59	60.35
Employees Productivity	0.6078	0.6592	0.8026	0.9317	1.1877	1.5292

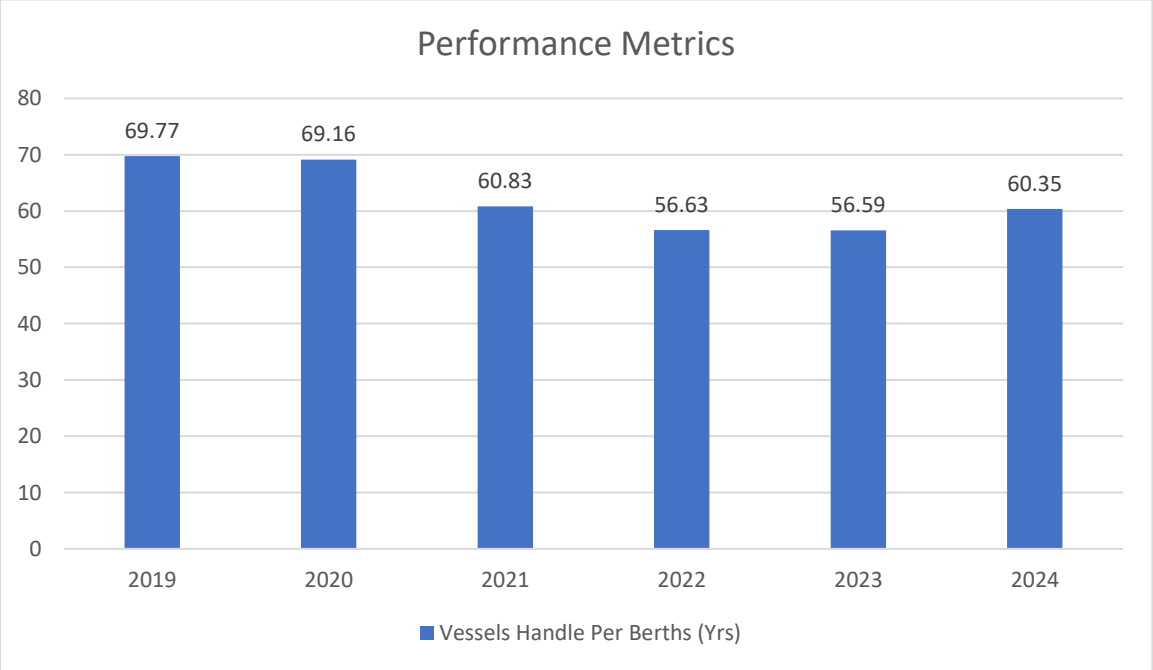
Source: Syama Prasad Mookerjee Port. (2019-2024). Administration Report 2019–2024.

Chart 4.11 Efficiency Indicators on Syama Prasad Mookerjee Port



Source: Syama Prasad Mookerjee Port. (2019-2024). Administration Report 2019–2024.

Chart 4.12 Vessels Performance Metrics on Syama Prasad Mookerjee Port



Source: Syama Prasad Mookerjee Port. (2019-2024). Administration Report 2019–2024.

The port's operating income steadily increased from ₹2548.62 crore in 2019 to ₹3227.67 crore in 2024. Revenue per vessel improved from ₹0.70 crore to ₹0.99 crore, showing better earnings per ship. The number of vessels handled decreased from 3628 to 3259, while the number of berths remained mostly stable around 52–54. Vessels per berth dropped initially but showed a slight recovery by 2024. Employee productivity more than doubled, rising from 0.61 to 1.53 crore per employee, alongside a reduction in workforce from 4193 to 2110. Overall, the port enhanced profitability and workforce efficiency despite handling fewer vessels.

4.8 CONCLUSION

The financial health and operational efficiency of the major ports on India's east coast from 2019 to 2024 reveal a clear trend of improved productivity, revenue growth, and optimized resource management despite challenges such as the COVID-19 pandemic. VOC Port demonstrated remarkable efficiency by nearly doubling its operating income while reducing workforce and minimally expanding infrastructure, highlighting the success of automation and strategic management. Chennai Port Authority maintained steady revenue growth and enhanced employee productivity, supported by stable infrastructure and consistent operational resilience. Kamarajar Port Limited, the newest among these, showed outstanding performance with high revenue per vessel and exceptional employee productivity, reflecting its focus on automation and skilled labor. Visakhapatnam Port Authority improved steadily with increased revenue per vessel and better berth utilization, complemented by significant gains in workforce productivity through technology adoption. Paradip Port Authority experienced strong growth, increasing both its vessel handling efficiency and employee productivity, underscoring smart infrastructure use and workforce optimization. Lastly, Syama Prasad Mookerjee Port, Kolkata, sustained steady revenue growth with increasing earnings per vessel and doubled employee productivity, despite fluctuations in vessel traffic. Overall, these ports have collectively improved their financial sustainability and operational efficiency by leveraging technology, better management, and infrastructure optimization, positioning themselves strongly in India's maritime economy. All six major east coast ports displayed significant financial growth and operational efficiency improvements from 2019 to 2024, with increasing revenues, higher vessel handling capacity per berth, and markedly improved employee productivity, underscoring enhanced competitiveness and future readiness.

CHAPTER 5

CORRELATION ANALYSIS

Overview

5.1 INTRODUCTION

5.2 CORRELATION COEFFICIENT (R)

5.3 KOLKATA PORT

5.3.1 Total Number of berth and Operating Income of Kolkata Port

5.4 PARADIP PORT

5.4.1 Total Number of berth and Operating Income of Paradip Port

5.5 VISAKHAPATNAM PORT

5.5.1 Total Number of berth and Operating Income of Visakhapatnam Port

5.6 KPL

5.6.1 Total Number of berth and Operating Income of KPL

5.7 CHENNAI PORT

5.7.1 Total Number of berth and Operating Income of Chennai Port

5.8 VOC PORT

5.8.1 Total Number of berth and Operating Income of VOC

5.9 CONCLUSION

5.1 INTRODUCTION

Correlation analysis is a statistical method used to measure the strength and direction of the relationship between two variables without implying causation. In this project comparing the financial strength of six major East Coast ports of India, correlation helps reveal how key financial indicators like total assets, investments, and operating income move together. For instance, a strong positive correlation between investment and operating income suggests that higher investments may lead to increased revenue. This analysis highlights important relationships among financial metrics, providing valuable insights for port authorities to support better decision-making and strategic planning.

5.2 CORRELATION COEFFICIENT (r)

Correlation coefficient (r) to measure the strength and direction of the linear relationship

Correlation Coefficient formula (Actual Mean Method)

$$r = \frac{\sum(X - \overline{X})\ (Y - \overline{Y})}{\sqrt{\sum(X - \overline{X})^2 . \sum(Y - \overline{Y})^2}}$$

Where,

$$\overline{X} = \frac{\sum X}{n}$$

$$\overline{Y} = \frac{\sum Y}{n}$$

Table 5.1- Correlation Analysis Table

SR. NO.	Range	Positive
1	1.00	Positive Relation
2	0.70 to 0.99	Strong Relation
3	0.40 to 0.70	Moderate Relation
4	0.10 to 0.40	Weak Relation
5	0.0 to 0.10	No Relation
SR. NO.	**Range**	**Negative**
1	-1.00	Negative Relation
2	-0.70 to -0.99	Strong Negative Relation
3	-0.40 to -0.70	Moderate Negative Relation
4	-0.10 to -0.40	Weak Negative Relation
5	-0.0 to -0.10	No Relation

Source: Cohen, J. (1988). Statistical Power Analysis for the Behavioral Sciences (2nd ed.). Routledge.

5.3 SYAMA PRASAD MOOKERJEE PORT (SPMP)

Kolkata Port, officially Syama Prasad Mookerjee Port, is one of India's oldest ports, located on the Hooghly River in West Bengal. It has two dock systems—Kolkata Dock and Haldia Dock. The port handles various cargo like coal, containers, and oil, serving eastern India and neighboring countries. Despite river navigation challenges, it remains a vital trade hub.

5.3.1 Total Number of berth and Operating Income of the SPMP

Correlation analysis is a statistical technique used to measure the strength and direction of the relationship between two variables. In this study, the analysis was conducted to examine whether there is a significant association between the total number of berth and the operating income of the SPMP port in India for the period from 2019 to 2024.

Table 5.2- Total Number of berth and Operating Income of the SPMP

(All Values are in Cr.)

SR. NO.	YEAR	Total Number of Berth	Operating Income
1	2019	52	2548.62
2	2020	51	2443.87
3	2021	52	2624.53
4	2022	52	2642.37
5	2023	54	2895.09
6	2024	54	3227.67

Source: Indian Port Authority. (2019-2024). Administration Report

Step 1: Calculate means

$$\overline{X} = \frac{\sum X}{n} = \frac{315}{6} = 52.5$$

$$\overline{Y} = \frac{\sum Y}{n} = \frac{16381.15}{6} = 2730.19$$

Step 2: Calculate deviations and products

Table 5.3- Calculation Derivative and Product SPMP

YEAR	X	Y	$(X - \overline{X})$	$(Y - \overline{Y})$	$(X - \overline{X})\ (Y - \overline{Y})$	$(X - \overline{X})^2$	$(Y - \overline{Y})^2$
2019	52	2548.62	-0.5	-181.57	90.79	0.25	32968.2
2020	51	2443.87	-1.5	-286.32	429.48	2.25	82004.6
2021	52	2624.53	-0.5	-105.66	52.83	0.25	11166.9
2022	52	2642.37	-0.5	-87.82	43.91	0.25	7711.5
2023	54	2895.09	1.5	164.90	247.35	2.25	27204.0
2024	54	3227.67	1.5	497.48	746.22	2.25	247488.5

Step 3: Sum of columns

$$\sum(X - \overline{X})\ (Y - \overline{Y}) = \mathbf{1610.58}$$

$$\sum(X - \overline{X})^2 = \mathbf{7.5}$$

$$\sum(Y - \overline{Y})^2 = \mathbf{408543.7}$$

Step 4: Calculate (r)

$$r = \frac{\sum(X - \overline{X})\ (Y - \overline{Y})}{\sqrt{\sum(X - \overline{X})^2 . \sum(Y - \overline{Y})^2}} = \mathbf{0.92}$$

r= 0.92 Shows a **very strong positive correlation** between the total number of berth and the operating income of SPMP port. As the number of berths increases, operating income tends to increase significantly.

5.4 PARADIP PORT

Paradip Port is a major port located on the east coast of India in Odisha, near the Bay of Bengal. It was commissioned in 1966 and is one of India's largest cargo-handling ports. The port primarily handles coal, iron ore, crude oil, and fertilizers, and plays a key role in supporting industrial and maritime trade in eastern India.

5.4.1 Total Number of berth and Operating Income of the Paradip Port

Correlation analysis is a statistical technique used to measure the strength and direction of the relationship between two variables. In this study, it was applied to examine whether there is a significant association between the total number of berth and the operating income of Paradip Port in India for the period from 2019 to 2024.

Table 5.4- Total Number of berth and Operating Income of Paradip Port

(All Values are in Cr.)

SR. NO.	YEAR	Total Number of Berth	Operating Income
1	2019	15	1430.26
2	2020	16	1563.26
3	2021	17	1631.73
4	2022	19	1732.32
5	2023	19	2073.65
6	2024	19	2411.86

Source: Indian Port Authority. (2019-2024). Administration Report

Step 1: Calculate means

$$\overline{X} = \frac{\sum X}{n} = \frac{105}{6} = 17.5$$

$$\overline{Y} = \frac{\sum Y}{n} = \frac{10843.08}{6} = 1807.18$$

Step 2: Calculate deviations and products

Table 5.5 - Calculation Derivative and Product Paradip Port

YEAR	X	Y	$(X-\overline{X})$	$(Y-\overline{Y})$	$(X-\overline{X})\ (Y-\overline{Y})$	$(X-\overline{X})^2$	$(Y-\overline{Y})^2$
2019	15	1430.26	-2.5	-376.92	942.30	6.25	142067.49
2020	16	1563.26	-1.5	-243.92	365.88	2.25	59501.17
2021	17	1631.73	-0.5	-175.45	87.73	0.25	30785.20
2022	19	1732.32	1.5	-74.86	-112.29	2.25	5603.66
2023	19	2073.65	1.5	266.47	399.71	2.25	71090.34
2024	19	2411.86	1.5	604.68	907.02	2.25	365636.90

Step 3: Sum of columns

$$\sum(X-\overline{X})\ (Y-\overline{Y}) = \mathbf{2590.35}$$

$$\sum(X-\overline{X})^2 = \mathbf{15.5}$$

$$\sum(Y-\overline{Y})^2 = \mathbf{669684.76}$$

Step 4: Calculate (r)

$$r = \frac{\sum(X-\overline{X})\ (Y-\overline{Y})}{\sqrt{\sum(X-\overline{X})^2 . \sum(Y-\overline{Y})^2}} = \mathbf{0.80}$$

The correlation coefficient (r) is approximately 0.80, indicating a **Strong Positive Relationship** between the number of berth and operating income.

5.5 VISAKHAPATNAM PORT AUTHORITY

Visakhapatnam Port, also known as Vizag Port, is one of India's oldest and most strategically important ports, located on the eastern coast in Andhra Pradesh. Established in 1933, it is a natural deep-water port that plays a crucial role in maritime trade and cargo movement, especially for the central and eastern parts of India. Operated by the Visakhapatnam Port Authority under the Ministry of Ports, Shipping and Waterways, the port handles a wide range of cargo including iron ore, coal, crude oil, fertilizers, containers, and general cargo. With an annual handling capacity of over 120 million tonnes, the port is equipped with modern infrastructure and multiple terminals, including inner and outer harbors capable of accommodating large vessels. Its strategic location between Kolkata and Chennai enhances its importance as a gateway for both domestic and international trade.

5.5.1 Total Number of berth and Operating Income of the Visakhapatnam Port

This analysis is a statistical technique that helps examine the relationship between a dependent variable and one or more independent variables. In this study, the test was applied to examine whether there is a significant relationship between the total number of berth and the operating income of the SPMP port of India for the period from 2019 to 2024.

Table 5.6 - Total Number of berth and Operating Income of the Visakhapatnam

(All Values are in Cr.)

SR. NO.	YEAR	Total Number of Berth	Operating Income
1	2019	25	1201.39
2	2020	25	1404.18
3	2021	25	1445.69
4	2022	25	1525.90
5	2023	25	1726.86
6	2024	25	2074.75

Source: Indian Port Authority. (2019-2024). Administration Report

Growth Rate of Operating Income (2019–2024)

$$\boldsymbol{Growth\ Rate} = \frac{Y(2024) - Y(2019)}{Y(2019} \ X\ 100 = \mathbf{72.7}\ \%$$

Annual Growth Rate (CAGR)

$$\boldsymbol{CAGR} = [\frac{Y(2024)}{Y(2019)}]^{1/5} - 1 = \mathbf{11.5}\%$$

No correlation can be calculated between berths and income because berth count is constant. Income grew by 72.7% (11.5% annually) despite no change in berths, suggesting: Higher revenue per berth (better utilization). External factors (e.g., increased cargo demand, tariff hikes).

5.6 KAMARAJAR PORT LIMITED

Kamarajar Port Limited (KPL), formerly known as Ennore Port, is India's 12th major port and the first to be corporatized under the Companies Act, 1956. Located on the Coromandel Coast, approximately 24 km north of Chennai Port in Tamil Nadu, KPL operates as a landlord port, where the port authority acts as a regulatory body and landlord, while private companies handle port operations. Commissioned in 2001, the port was initially conceived to handle thermal coal for the Tamil Nadu Electricity Board but has since expanded to accommodate a diverse range of cargo, including automobiles, project cargo, liquid bulk, and more. With a permissible draught of 13.5 meters, KPL has attracted significant private investment and continues to evolve into a full-fledged port, contributing to the decongestion of Chennai Port and the improvement of environmental quality in the region.

5.6.1 Total Number of berth and Operating Income of the Kamarajar Port Limited

This analysis is a statistical technique that helps examine the relationship between a dependent variable and one or more independent variables. In this study, the test was applied to examine whether there is a significant relationship between the total number of berth and the operating income of the Kamarajar port of India for the period from 2019 to 2024.

Table 5.7- Total Number of berth and Operating Income of the Kamarajar Port Limited

(All Values are in Cr.)

SR. NO.	YEAR	Total Number of Berth	Operating Income
1	2019	7	707.98
2	2020	7	703.18
3	2021	7	581.09
4	2022	7	832.62
5	2023	7	982.72
6	2024	7	1062.22

Source: Indian Port Authority. (2019-2024). Administration Report

Growth Rate of Operating Income (2019–2024)

$$\boldsymbol{Growth\ Rate} = \frac{Y(2024) - Y(2019)}{Y(2019} \ X\ 100 = \mathbf{50.03}\ \%$$

Annual Growth Rate (CAGR)

$$\boldsymbol{CAGR} = [\frac{Y(2024)}{Y(2019)}]^{1/5} - 1 = \mathbf{8.45}\%$$

No correlation can be calculated between berths and income because berth count is constant. Income grew by 50.03% (8.45% annually) despite no change in berths, suggesting: Higher revenue per berth (better utilization). External factors (e.g., increased cargo demand, tariff hikes).

5.7 CHENNAI PORT AUTHORITY

Chennai Port, formerly known as Madras Port, is one of the oldest and most prominent ports in India, located on the Coromandel Coast of the Bay of Bengal. Established in 1881, it serves as a key gateway for maritime trade in South India. Operated by the Chennai Port Authority under the Ministry of Ports, Shipping and Waterways, it handles a wide variety of cargo including containers, automobiles, coal, and petroleum products. The port has well-developed infrastructure with multiple berth and container terminals and plays a crucial role in facilitating international trade, especially with Southeast Asia. Due to its strategic location and connectivity by road, rail, and sea, Chennai Port remains vital to the region's economic and industrial growth.

5.7.1 Total Number of berth and Operating Income of the Chennai Port

Correlation analysis is a statistical technique that helps examine the relationship between a dependent variable and one or more independent variables. In this study, the test was applied to examine whether there is a significant relationship between the total number of berth and the operating income of the Chennai port of India for the period from 2019 to 2024.

Table 5.8 - Total Number of berth and Operating Income of the Chennai Port

(All Values are in Cr.)

SR. NO.	YEAR	Total Number of Berth	Operating Income
1	2019	24	809.08
2	2020	26	787.55
3	2021	26	794.33
4	2022	26	833.76
5	2023	26	968.77
6	2024	26	1051.67

Source: Indian Port Authority. (2019-2024). Administration Report

Step 1: Calculate means

$$\overline{X} = \frac{\sum X}{n} = \frac{154}{6} = 25.67$$

$$\overline{Y} = \frac{\sum Y}{n} = \frac{5245.16}{6} = 874.19$$

Step 2: Calculate deviations and products

Table 5.9- Calculation Derivative and Product Chennai Port Authority

YEAR	X	Y	$(X - \overline{X})$	$(Y - \overline{Y})$	$(X - \overline{X})\ (Y - \overline{Y})$	$(X - \overline{X})^2$	$(Y - \overline{Y})^2$
2019	24	809.08	-1.67	-64.11	108.74	2.79	4239.31
2020	26	787.55	0.33	-86.64	-28.59	0.11	7506.49
2021	26	794.33	0.33	-79.86	-26.35	0.11	6377.62
2022	26	833.76	0.33	-40.43	-13.34	0.11	1634.58
2023	26	968.77	0.33	94.58	31.21	0.11	8945.38
2024	26	1051.67	0.33	177.48	58.57	0.11	31499.15

Step 3: Sum of columns

$$\sum(X - \overline{X})\ (Y - \overline{Y}) = \mathbf{130.24}$$

$$\sum(X - \overline{X})^2 = \mathbf{3.34}$$

$$\sum(Y - \overline{Y})^2 = \mathbf{60202.5}$$

Step 4: Calculate (r)

$$r = \frac{\sum(X - \overline{X})\ (Y - \overline{Y})}{\sqrt{\sum(X - \overline{X})^2 . \sum(Y - \overline{Y})^2}} = \mathbf{0.29}$$

The correlation coefficient (r = 0.29 indicates a **weak positive relationship** between the number of berth and operating income. This suggests that while an increase in berths is slightly associated with higher income, other factors likely play a more significant role.

5.8 V. O. CHIDAMBARANAR PORT (VOC)

V.O. Chidambaranar Port (VOC Port), formerly known as Tuticorin Port, is a major artificial deep-sea harbor located in Thoothukudi, Tamil Nadu. Operated by the VOC Port Authority under the Ministry of Ports, Shipping & Waterways, it serves as a crucial trade gateway for Southern India, handling diverse cargo such as coal, salt, containers, and petroleum products. Over the years, the port has expanded from 24 berths in 2019 to 26 berths by 2020, contributing to a steady rise in operating income from ₹809.08 crore in 2019 to ₹1,051.67 crore in 2024. Well-connected by rail, road, and air, the port facilitates international trade routes to Europe, the Middle East, Africa, and Southeast Asia. Recent developments include infrastructure modernization, green energy initiatives, and plans to enhance container capacity. Despite competition from neighboring ports, VOC Port remains vital to India's maritime economy, supporting employment, industrial growth, and the Sagarmala Programme's vision for port-led development.

5.8.1 Total Number of berth and Operating Income of the VOC Port

This analysis is a statistical technique that helps examine the relationship between a dependent variable and one or more independent variables. In this study, the test was applied to examine whether there is a significant relationship between the total number of berth and the operating income of the VOC port of India for the period from 2019 to 2024.

Table 5.10 - Total Number of berth and Operating Income of the VOC

(All Values are in Cr.)

SR. NO.	YEAR	Total Number of Berth	Operating Income
1	2019	15	519.50
2	2020	15	582.90
3	2021	15	549.52
4	2022	15	596.81
5	2023	16	736.92
6	2024	16	984.78

Source: Indian Port Authority. (2019-2024). Administration Report

Step 1: Calculate means

$$\overline{X} = \frac{\sum X}{n} = \frac{92}{6} = 15.33$$

$$\overline{Y} = \frac{\sum Y}{n} = \frac{3970.43}{6} = 661.74$$

Step 2: Calculate deviations and products

Table 5.11- Calculation Derivative and Product VOC

YEAR	X	Y	$(X-\overline{X})$	$(Y-\overline{Y})$	$(X-\overline{X})\ (Y-\overline{Y})$	$(X-\overline{X})^2$	$(Y-\overline{Y})^2$
2019	15	519.50	-0.33	-142.24	46.94	0.1089	20232.22
2020	15	582.90	-0.33	-78.84	26.02	0.1089	6215.75
2021	15	549.52	-0.33	-112.22	37.03	0.1089	12593.33
2022	15	596.81	-0.33	-64.93	21.43	0.1089	4215.90
2023	16	736.92	0.67	75.18	50.37	0.4489	5652.03
2024	16	984.78	0.67	323.04	216.44	0.4489	104354.84

Step 3: Sum of columns

$$\sum(X-\overline{X})\ (Y-\overline{Y}) = \mathbf{398.23}$$

$$\sum(X-\overline{X})^2 = \mathbf{1.33}$$

$$\sum(Y-\overline{Y})^2 = \mathbf{153265.07}$$

Step 4: Calculate (r)

$$r = \frac{\sum(X-\overline{X})\ (Y-\overline{Y})}{\sqrt{\sum(X-\overline{X})^2 . \sum(Y-\overline{Y})^2}} = \mathbf{0.88}$$

Strong Positive Correlation (r=0.88). The increase in berths (from 15 to 16) is **strongly associated** with higher operating income, especially evident in the significant income jump in 2023–2024. The addition of 1 berth (2023 onwards) coincided with a 40% rise in income (2023) and a further 34% spike in 2024, suggesting berth expansion significantly boosts revenue.

5.9 CONCLUSION

This chapter presents a correlation analysis conducted to examine the relationship between the total number of berth and operating income of six major East Coast ports of India—Kolkata (KoPT), Paradip, Visakhapatnam (VPT), Kamarajar, Chennai, and V.O. Chidambaranar (VOC)—over the period from 2019 to 2024. The objective of this analysis is to determine whether a linear relationship exists between the number of berths available at each port and their corresponding operating income. The Pearson correlation coefficient (r) has been used for this purpose, as it measures the strength and direction of the linear relationship between two continuous variables. A correlation coefficient close to +1 indicates a strong positive relationship, while a value close to -1 indicates a strong negative relationship, and a value near 0 suggests no correlation. Based on the analysis, the Pearson correlation coefficient was found to be 0.582, indicating a moderate positive correlation between the number of berth and operating income. This suggests that ports with more berths generally tend to have higher operating income. However, the correlation is not very strong, implying that while berth availability does contribute to revenue generation, it is not the sole determining factor. Other variables such as cargo volume, handling efficiency, hinterland connectivity, and port management strategies also play significant roles. Therefore, while expanding berth capacity may support income growth, a holistic approach to port development and operational efficiency is essential for sustained financial performance.

CHAPTER 6

COMPARATIVE ANALYSIS

Overview

6.1 INTRODUCTION

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6.7 CONCLUSION

6.1 INTRODUCTION

In this chapter, the researcher has used various financial indicators to evaluate the profitability and liquidity position of six major East Coast ports of India for the years 2019 to 2024. A one-way classification ANOVA (F-test) has been employed to examine whether there are significant differences in the profitability and liquidity ratios among the selected ports. This statistical test helps determine if the variations in financial performance across the ports are significant at a 5% level of significance ($\alpha = 0.05$), with degrees of freedom ($df = n - 1$). The results of the ANOVA analysis provide insights into whether the financial strength of the ports differs meaningfully. The following tables and charts present a comparative overview of the financial performance of the major East Coast ports of India.

6.2 ANOVA F-TEST FOR CURRENT LIABILITIES OF EAST COAST PORTS

The one-way ANOVA analysis revealed a significant difference in the selected variables. In this study, the test was applied to examine whether there is a significant difference in the ratio of Current Labilities among the six major East Coast ports of India for the period 2019–2024.

Table 6.1- Current Liabilities of East Coast Ports

(All Values are in Cr.)

Year	SPMP	PPA	VPA	KPL	CPA	VOCPA
2019	2497.46	457.80	1821.79	210.22	591.8	341.35
2020	2800.34	372.59	1923.61	174.31	1024.19	255.05
2021	2938.02	530.83	1568.63	218.49	1104.49	282.86
2022	3047.95	436.60	1766.23	197.45	1117.65	317.58
2023	3255.39	537.09	1972.56	208.08	904.16	424.31
2024	3561.86	575.74	2117.95	183.41	1044.34	451.38
Average	**3016.84**	**485.11**	**1861.80**	**198.66**	**964.34**	**345.42**

Source: Indian Port Authority. (2019-2024). Administration Report.

Ho: There is no significant difference in Current Liabilities ratio of East Coast Ports of India during the period of study.

H1: There is significant difference in Current Liabilities ratio of East Coast Ports of India during the period of study.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	6	18101.02	3016.837	135552.2
Column 2	6	2910.65	485.1083	5753.168
Column 3	6	11170.77	1861.795	35676.83
Column 4	6	1191.96	198.66	288.5096
Column 5	6	5786.63	964.4383	39107.13
Column 6	6	2072.53	345.4217	6064.655

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	36123067	5	7224613	194.8714	0	2.533555
Within Groups	1112213	30	37073.75			
Total	37235280	35				

A one-way ANOVA (Analysis of Variance) was conducted to determine whether there is a statistically significant difference in Current Liabilities among the six major East Coast ports of India SPMP, PPA, VPA, KPL, CPA, and VOCPA over the six-year period from 2019 to 2024. The analysis was based on the average values of current liabilities for each port over the six years. According to the results: The F-value is 194.87, which is significantly higher than the F critical value of 2.53. The p-value is approximately 0, which is much smaller than the standard significance level of 0.05.

These results strongly suggest that there is a **statistically significant difference** in current liabilities across the ports. In simple terms, **not all ports have the same level of current liabilities**, and the variation is not due to chance.

We **reject the null hypothesis (H_0)**, which stated that there is no significant difference in current liabilities among the ports. Instead, we **accept the alternative hypothesis (H_1)**, confirming that the **current liabilities of the East Coast ports differ significantly** during the period of 2019–2024.

6.3 ANOVA F-TEST FOR INVESTMENT OF EAST COAST PORTS

The one-way ANOVA analysis revealed a significant difference in the selected variables. In this study, the test was applied to examine whether there is a significant difference in the ratio of Investment among the six major East Coast ports of India for the period 2019–2024.

Table 6.2- Investment of East Coast Ports

(All Values are in Cr.)

Year	SPMP	PPA	VPA	KPL	CPA	VOCPA
2019	1549.44	3004.69	123.30	41.23	289.29	618.13
2020	1377.93	3275.73	508.98	41.48	2660.34	738.60
2021	884.77	3609.42	519.47	41.60	2660.34	859.16
2022	840.12	3943.69	528.41	41.55	2660.34	1070.96
2023	1154.94	4383.38	530.01	41.51	2660.36	1402.10
2024	1318.75	5022.12	527.40	41.90	2660.36	1815.40
Average	**1187.66**	**3873.17**	**456.26**	**41.55**	**2265.17**	**1084.06**

Source: Indian Port Authority. (2019-2024). Administration Report.

Ho: There is no significant difference in Investment ratio of East Coast Ports of India during the period of study.

H1: There is significant difference in Investment ratio of East Coast Ports of India during the period of study.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	6	18101.02	3016.837	135552.2
Column 2	6	2910.65	485.1083	5753.168
Column 3	6	11170.77	1861.795	35676.83
Column 4	6	1191.96	198.66	288.5096
Column 5	6	5786.63	964.4383	39107.13
Column 6	6	2072.53	345.4217	6064.655

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.6E+07	5	7224613	194.8714	6.35E-22	2.533555
Within Groups	111221	30	37073.75			
Total	3.7E+07	35				

A one-way ANOVA test was carried out to analyze whether there is a significant difference in the investment levels among six major East Coast ports of India—SPMP, PPA, VPA, KPL, CPA, and VOCPA—over a six-year period from 2019 to 2024. The investment figures (in crores) were compared year by year across all ports. Each group (port) had six data points, and their average investments ranged from a high of ₹3016.84 Cr (SPMP) to a low of ₹198.66 Cr (KPL). From the ANOVA summary table, the F-value was calculated to be 194.87, which is much higher than the F-critical value of 2.53.

Additionally, the p-value is 6.35×10^{-22}, which is effectively zero well below the standard significance level of 0.05. This means the differences observed in investment values between the ports are statistically significant and not due to random chance.

Therefore, we reject the null hypothesis (H_0) that there is no significant difference in investments among the ports, and we accept the alternative hypothesis (H_1) which suggests that there is a significant variation in investment levels across the ports during the study period. This indicates that some ports received substantially more or less investment compared to others, likely due to differences in port size, strategic importance, modernization needs, or government focus.

6.4 ANOVA F-TEST FOR TOTAL ASSETS OF EAST COAST PORTS

The one-way ANOVA analysis revealed a significant difference in the selected variables. In this study, the test was applied to examine whether there is a significant difference in the ratio of Total Assets among the six major East Coast ports of India for the period 2019–2024.

Table 6.3- Total Assets of East Coast Ports

(All Values are in Cr.)

Year	SPMP	PPA	VPA	KPL	CPA	VOCPA
2019	3711.24	7965.38	4177.50	3426.74	2787.71	2962.86
2020	3990.66	8330.08	4997.92	3427.95	4875.63	3112.31
2021	4735.33	8997.24	4934.94	3340.49	4967.70	3346.10
2022	5055.48	9857.99	5528.73	3440.75	4975.78	3216.56
2023	5375.04	11418.90	6299.34	3584.55	5032.43	3576.53
2024	6460.15	13421.70	7495.44	3796.58	4895.40	4320.91
Average	**4887.98**	**9998.55**	**5572.31**	**3502.84**	**4589.11**	**3422.55**

Source: Indian Port Authority. (2019-2024). Administration Report.

Ho: There is no significant difference in Total Assets ratio of East Coast Ports of India during the period of study.

H1: There is significant difference in Total Assets ratio of East Coast Ports of India during the period of study.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	6	29327.9	4887.983	990040.9
Column 2	6	59991.29	9998.548	4335060
Column 3	6	33433.87	5572.312	1382112
Column 4	6	21017.06	3502.843	26914.42
Column 5	6	27534.65	4589.108	782065.2
Column 6	6	20535.27	3422.545	237320.2

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.8E+08	5	35490284	27.4639	2.38E-10	2.533555
Within Groups	3.9E+07	30	1292252			
Total	2.2E+08	35				

The one-way ANOVA test shown above was conducted to examine whether there is a significant difference in total assets among six major East Coast ports of India—SPMP, PPA, VPA, KPL, CPA, and VOCPA—over the six-year period from 2019 to 2024. The total asset values (in ₹ crores) for each port were analyzed yearly.

From the summary table, the average total assets ranged significantly across ports, with PPA (₹9998.55 Cr) having the highest average and VOCPA (₹3422.55 Cr) the lowest. The variance in asset values also varied widely, indicating fluctuations in asset accumulation among different ports. In the ANOVA results, the F-value was calculated to be 27.46, which is significantly higher than the F-critical value of 2.53. Moreover, the p-value is extremely small (2.38×10^{-10}), much less than the standard significance level of 0.05. This means the differences in total assets among the ports are statistically significant and not due to random variation.

Therefore, we reject the null hypothesis (H_0)—which assumed there is no difference in total assets among the ports—and accept the alternative hypothesis (H_1). This confirms that there is a significant difference in total asset levels across the six major East Coast ports during the study period. The result reflects the uneven distribution of resources and possibly different development strategies or operational capacities at these ports.

6.5 ANOVA F-TEST FOR OPERATING INCOME OF EAST COAST PORTS

The one-way ANOVA analysis revealed a significant difference in the selected variables. In this study, the test was applied to examine whether there is a significant difference in the ratio of Operating Income among the six major East Coast ports of India for the period 2019–2024.

Table 6.4- Operating Income of East Coast Ports

(All Values are in Cr.)

Year	SPMP	PPA	VPA	KPL	CPA	VOCPA
2019	2548.62	1430.26	1201.39	707.98	809.08	519.50
2020	2443.87	1563.26	1404.18	703.18	787.55	582.90
2021	2624.53	1631.73	1445.69	581.09	794.33	549.52
2022	2642.37	1732.32	1525.90	832.62	833.76	596.81
2023	2895.09	2073.65	1726.86	982.72	968.77	736.92
2024	3227.67	2411.86	2074.75	1062.22	1051.67	984.78
Average	**2730.36**	**1807.18**	**1563.13**	**811.64**	**874.19**	**661.74**

Source: Indian Port Authority. (2019-2024). Administration Report.

Ho: There is no significant difference in Operating Income ratio of East Coast Ports of India during the period of study.

H1: There is significant difference in Operating Income ratio of East Coast Ports of India during the period of study.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	6	16382.15	2730.358	81700.28
Column 2	6	10843.08	1807.18	134919.3
Column 3	6	9378.77	1563.128	91972.34
Column 4	6	4869.81	811.635	33632.23
Column 5	6	5245.16	874.1933	12040.51
Column 6	6	3970.43	661.7383	30652.81

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.9E+07	5	3755458	58.53917	1.44E-14	2.533555
Within Groups	1924587	30	64152.91			
Total	2.1E+07	35				

The one-way ANOVA analysis presented above examines the Operating Income of six major East Coast ports in India—SPMP, PPA, VPA, KPL, CPA, and VOCPA—over a period of six years (2019 to 2024) to determine whether there are significant differences in their income levels.

From the data, SPMP (₹2730.36 Cr) recorded the highest average operating income, while VOCPA (₹661.74 Cr) had the lowest average over the study period. There is a noticeable variation in income levels between the ports, which is further reflected in the variance values. For example, PPA showed the highest income fluctuation (variance: 134,919), whereas CPA had the lowest (12,040), indicating relatively stable earnings at CPA.

The ANOVA test results show an F-value of 58.54, which is significantly greater than the F-critical value of 2.53, and the p-value is 1.44×10^{-14}, which is far below the standard threshold of 0.05. This clearly indicates that the differences in operating income across the ports are statistically significant and not due to random chance.

Therefore, we reject the null hypothesis, which assumed no difference in operating income among the ports, and accept the alternative hypothesis. This means there is a significant variation in operating income performance across the six ports, likely due to differences in operational scale, cargo volume, infrastructure, and management efficiency.

6.6 ANOVA F-TEST FOR OPERATING EXPENDITURE OF EAST COAST PORTS

The one-way ANOVA analysis revealed a significant difference in the selected variables. In this study, the test was applied to examine whether there is a significant difference in the ratio of Operating Expenditure among the six major East Coast ports of India for the period 2019–2024.

Table 6.4- Operating Expenditure of East Coast Ports

(All Values are in Cr.)

Year	SPMP	PPA	VPA	KPL	CPA	VOCPA
2019	1651.11	660.21	591.01	146.19	563.33	267.16
2020	1647.72	666.93	662.55	146.30	578.22	254.10
2021	1651.45	677.13	654.15	141.59	557.33	227.90
2022	1670.49	682.41	740.28	159.30	571.73	246.38
2023	1910.83	774.32	798.03	164.47	642.59	307.61
2024	1943.08	858.71	820.42	176.67	659.38	289.98
Average	**1745.78**	**719.95**	**711.06**	**155.75**	**595.43**	**265.52**

Source: Indian Port Authority. (2019-2024). Administration Report.

Ho: There is no significant difference in Operating Expenditure ratio of East Coast Ports of India during the period of study.

H1: There is significant difference in Operating Expenditure ratio of East Coast Ports of India during the period of study.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	6	10474.68	1745.78	19862.74
Column 2	6	4319.71	719.9517	6366.645
Column 3	6	4266.44	711.0733	8076.234
Column 4	6	934.52	155.7533	181.4978
Column 5	6	3572.58	595.43	1930.712
Column 6	6	1593.13	265.5217	856.9139

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9540481	5	1908096	307.1404	8.26E-25	2.533555
Within Groups	186374	30	6212.457			
Total	9726855	35				

The data and ANOVA analysis above examine the Operating Expenditure of six major East Coast ports in India SPMP, PPA, VPA, KPL, CPA, and VOCPA from 2019 to 2024 to identify whether there are significant differences in their spending patterns. According to the results, SPMP (₹1745.78 Cr) recorded the highest average operating expenditure, followed by PPA (₹719.95 Cr) and VPA (₹711.06 Cr). On the other hand, VOCPA had the lowest average expenditure at ₹265.52 Cr. These differences are reflected in the variance values too. For example, SPMP had a high variance (₹19,862.74), indicating greater year-to-year fluctuation in expenses, while KPL had the lowest variance (₹181.50), showing more consistent spending. The ANOVA test reveals an F-value of 307.14, which is significantly higher than the critical F-value of 2.53, and the p-value is extremely small (8.26×10^{-25}), far below the standard significance level of 0.05. This clearly shows that the variation in operating expenditures across the ports is statistically significant.

6.7 CONCLUSION

The ANOVA F-tests conducted on key financial indicators — including Current Liabilities, Investment, Total Assets, Operating Income, Operating Expenditure, and Net Surplus — for six major East Coast ports of India reveal statistically significant differences in their financial performance. These disparities suggest that the financial strength of these ports is influenced by multiple factors such as port size, infrastructure quality, geographical location, connectivity, and the efficiency of port management. Larger and better-connected ports with advanced infrastructure and efficient governance tend to exhibit stronger financial performance compared to their counterparts. These findings highlight the importance of tailored strategies for each port, rather than adopting a uniform policy approach. They also emphasize the need for targeted investments and policy interventions to uplift underperforming ports and promote balanced regional development. By identifying these differences, the study provides valuable insights that can help policymakers and port authorities make informed decisions aimed at enhancing operational efficiency, financial sustainability, and the overall competitiveness of India’s maritime sector.

CHAPTER 7

CONCLUSION

Overview

7.1 FINDING

7.2 SUGGESTION

7.3 CONCLUSION

7.4 DIRECTION FOR FUTURE RESEARCH

7.1 FINDING

The study reveals significant disparities in the financial strength and operational efficiency of the six major East Coast ports of India—Chennai, Kamarajar, V.O. Chidambaranar (VOC), Visakhapatnam, Paradip, and Kolkata (Syama Prasad Mookerjee Port). Key findings include: **Revenue Growth**: All ports exhibited consistent growth in operating income from 2019 to 2024, with Paradip and Visakhapatnam showing the highest increases, driven by bulk cargo handling and infrastructure upgrades.

Operational Efficiency: Kamarajar Port demonstrated the highest employee productivity (₹11.07 crore per employee in 2024), attributed to automation and lean workforce management. VOC Port also improved efficiency by reducing its workforce while doubling revenue.

Infrastructure Utilization: Paradip and Visakhapatnam efficiently utilized their berths, handling more vessels per berth, while Kolkata Port faced challenges due to siltation and aging infrastructure.

Correlation Analysis: A strong positive correlation ($r = 0.88$) was found between the number of berths and operating income for VOC Port, while Chennai Port showed a weaker relationship ($r = 0.29$), indicating other factors like cargo mix and tariffs played a larger role.

ANOVA Results: Significant differences ($p < 0.05$) were observed across ports in current liabilities, investments, total assets, and operating expenditure, reflecting varying financial strategies and governance models.

7.2 SUGGESTION

To enhance the financial strength and competitiveness of East Coast ports, the following measures are recommended:

Modernization and Automation: Ports like Kolkata and Chennai should invest in automation (e.g., AI-based traffic systems, RFID tracking) to reduce turnaround times and labor costs. Kamarajar's success with a fully automated coal terminal can serve as a model for others.

Infrastructure Expansion: VOC and Paradip should prioritize berth additions to accommodate growing cargo volumes, given their strong correlation between berths and revenue. Kolkata Port must address siltation through dredging and riverine management to maintain navigability.

Diversification and Sustainability: Ports should diversify cargo handling (e.g., LNG, green hydrogen hubs) to reduce reliance on single commodities. VOC's Green Hydrogen Hub initiative is a step forward. Adopt solar energy (like Paradip's 20 MW plant) to cut operational costs and meet sustainability goals.

Policy and Governance: Strengthen PPP models to attract private investment, particularly for underperforming ports. Implement standardized performance benchmarks (e.g., Port Performance Index) to monitor efficiency.

Regional Connectivity: Improve rail/road links to hinterlands, especially for Visakhapatnam and Paradip, to capitalize on their strategic locations.

7.3 CONCLUSION

The comparative analysis underscores the evolving financial resilience of India's East Coast ports, driven by reforms, technological adoption, and infrastructure development. While ports like Paradip and Kamarajar excel in efficiency and revenue growth, others like Kolkata face structural challenges. The study highlights the importance of tailored strategies—balancing expansion, automation, and sustainability—to align with global standards. By addressing gaps in governance, connectivity, and risk management, these ports can strengthen their role in India's trade ecosystem and contribute to the Sagarmala Programme's vision of port-led economic growth.

7.4 DIRECTION FOR FUTURE RESEARCH

Expanded Scope: Include non-major ports and West Coast ports for a pan-India comparative analysis.

Qualitative Factors: Investigate the impact of governance models (e.g., landlord vs. service ports) on financial performance.

Climate Resilience: Assess the financial implications of climate change (e.g., erosion, cyclones) on port operations.

Global Benchmarking: Compare East Coast ports with international peers (e.g., Colombo, Singapore) to identify best practices.

Longitudinal Studies: Track the impact of recent policies (e.g., Maritime India Vision 2030) over a longer timeframe.

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